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UPLAND DETENTION/RETENTION DEMONSTRATION PROJECT FINAL REPORT

IMPACTS OF AGRICULTURAL LAND USE ON WATER QUALITY AND UTILIZATION OF WETLANDS FOR DETENTION/RETENTION IN THE KISSIMMEE RIVER BASIN

This public document was promulgated at an annual cost of $14.05 or $2.80 per copy to inform the public regarding water resource studies of the District RP 1089 5C

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TABLE OF CONTENTS

	Page
List of Figures	i
List of Tables	vii
Section I - Executive Summary and Conclusions	1
Background and Project Description	1
District Activities	3
Construction	3
Wildcat Slough	3
Peavine Pasture	3
Armstrong Slough	4
Ash Slough	4
SEZ Dairy	4
Hydrology	4
Water Quality Sampling	4
Laboratory	5
Data Interpretation and Reports	5
Results	5
Land Use/Water Quality Impacts	5
Wetlands as Detention/Retention Facilities	14
Section II - Introduction	34
Historical Perspective	34
Report Organization	34
Acknowledgements	35
General Area	35
Specific Project Study Sites	35
Wildcat Slough	35
Ash Slough	36
Armstrong Slough	36
Peavine Pasture	41
SEZ Dairy	41
Section III - Field and Laboratory Methods	45
Introduction	45
Site Preparation	45
Wildcat Slough	45
Ash Slough	45
Armstrong Slough	46
Peavine Pasture	46
SEZ Dairy	46

Hydrology 46
Flow Control/Measurement Structures 46
Flumes 46
Culverts 48
Open Channel Rating 48
Data Collection and Verification 48

Water Quality 50
Routine Sampling 50
Storm Event Sampling 50
Rainfall 51

Laboratory 51

Data Processing 51

Section IV - Rainfall Analysis 52

Introduction 52

Methods 52

Results 55
Rainfall Quantity 55
Wildcat Slough 55
Ash Slough 57
Armstrong Slough 57
Peavine Pasture 57
SEZ Dairy 57
Summary 57
Rainfall Quality 62
Loading Rates 64
Watershed Nutrient Loading 64

Section V - Surface Water Quality Studies 68

Introduction 68

Armstrong Slough - North 69
Time Series Data 69
Armstrong Slough North Loading/Export 75

Armstrong Slough - South 76
Time Series Data 76
Armstrong Slough South Loading/Export 79

Peavine Pasture 79
Time Series Data 79
Peavine Pasture Loading/Export 91

Wildcat Slough 91
Wildcat Slough East 93
Time Series Data 93
Wildcat Slough East Loading/Export 93
Wildcat Slough West 93
Time Series Data 93
Wildcat Slough West Loading/Export 101

Wildcat Slough Total Watershed 101

Ash Slough East 109
Time Series Data 109
Ash Slough East Loading/Export 113

Ash Slough West 113
Time Series Data 113
Ash Slough West Loading/Export 121

SEZ Dairy 126
SEZ Dairy Outfall Time Series Data 126
SEZ Dairy Loading/Export 131

Upland Demonstration Project Sites Land Use/Water 133

Section VI Utilization of Wetlands as Detention/Retention for Enhancement of Quality of Nonpoint Source Agricultural Runoff 152

Introduction 152

Ash Slough 152
Methods 153
Event 1 155
Event 2 155
Event 3 160
Event 4 168
Event 5 168
Annual Water and Nutrient Budgets 173

Armstrong Slough 180
Methods 181
Time Series Data 181
Mass Loadings and Uptake 186

Comparison of Ash and Armstrong Slough Detention/ Retention Wetlands 189

Discussion 201

Bibliography 207

Appendix I - Monthly and Annual Watershed Water and Nutrient Budgets for Upland Demonstration Project Sites 210

Appendix II - Monthly and Annual Water and Nutrient Budgets at the Ash Slough Armstrong Slough Detention/Retention Wetlands 331

Appendix III - Site Comparison Data Summary Tables 362

LIST OF FIGURES

Page

I-1 General Area and Study Sites for the Upland Detention/Retention Demonstration Project 2

I-2 Armstrong Slough Channel Plug and Diversion Ditches 5

I-3 Floor Plan of Okeechobee Environmental Research Center 7

I-4 Means and Ranges of Total and Dissolved Inorganic Nitrogen Concentrations in Runoff from Upland Demonstration Project Sites 10

I-5 Means and Ranges of Total and Ortho Phosphorus Concentrations in Runoff from Upland Demonstration Project Sites 11

I-6 Mean Annual Export Versus Loading Rates on Upland Demonstration Project Watersheds 12

I-7 Flow Weighted Total Phosphorus Concentrations in Runoff from Pastures at Ash Slough 13

I-8 Time Series Concentrations Armstrong Slough Station 1 Turbidity and Color 20

I-9 Time Series Concentrations Armstrong Slough-Station 1 pH and Conductivity 21

I-10 Time Series Concentrations Armstrong Slough-Station 1 Inorganic and Total N 22

I-11 Time Series Concentrations Armstrong Slough-Station 1 Ortho and Total P 23

I-12 Uptake/Export Versus Loading Rates for Nitrogen in Upland Demonstration Project Detention/Retention Wetlands 26

I-13 Uptake/Export Versus Loading Rates for Phosphorus in Upland Demonstration Project Detention/Retention Wetlands 27

I-14 Total P Uptake Versus Loading on Selected Watersheds 29

I-15 Uptake Versus Loading Rates for Total Nitrogen on Pastures and Wetlands in the Kissimmee River Valley 30

I-16 Uptake Versus Loading Rates for Total Phosphorus on Pastures and Wetlands in the Kissimmee River Valley 31

II-1 Upland Demonstration Project Study Area 36

II-2 Wildcat Slough-Conveyance Channels and Sampling Stations 37

II-3 Ash Slough-Detention/Retention Marsh and Tributary Watersheds 39

II-4 Armstrong Slough and Adjacent Watersheds 40

II-5 Armstrong Slough-Detention/Retention Wetland 42

II-6 Peavine Pasture Watershed 43

II-7 SEZ Dairy-Watershed and Lagoon 44

III-1 Schematic of Critical Depth Flume for Flow Measurements 47

III-2 Horizontal Schematic of Culvert with Riser Flow Control Structure 49

IV-1 Wildcat Slough-Percent Historical Average of Monthly Rainfall During Upland Detention/Retention Project 56

IV-2 Ash Slough-Percent Historical Average of Monthly Rainfall During Upland Detention/Retention Project 58

IV-3 Armstrong Slough-Percent Historical Average of Monthly Rainfall During Upland Detention/Retention Project 59

IV-4 Peavine Pasture-Percent Historical Average of Monthly Rainfall During Upland Detention/Retention Project 60

IV-5 SEZ Dairy-Percent Historical Average of Monthly Rainfall During Upland Detention/Retention Project 61

V-1 Time Series Concentrations-Armstrong Slough North Watershed, Turbidity and Color 70

V-2 Time Series Concentrations-Armstrong Slough North Watershed, pH and Conductivity 71

V-3 Time Series Concentrations-Armstrong Slough North Watershed, Inorganic and Total N 72

V-4 Time Series Concentrations-Armstrong Slough North Watershed, Ortho and Total P 73

V-5 Annual Mean Concentrations of Total Discharge at Armstrong Slough North Watershed 74

V-6 Annual Mean Nitrogen and Phosphorus Export Rates from Armstrong Slough North Watershed 77

V-7 Time Series Concentrations-Armstrong Slough South Watershed, pH and Conductivity 78

V-8 Time Series Concentrations-Armstrong Slough South Watershed, Turbidity and Color 80

V-9 Time Series Concentrations-Armstrong Slough South Watershed, Inorganic and Total N 81

V-10 Time Series Concentrations and Total Discharge at Armstrong Slough South Watershed, Ortho and Total P 82

V-11 Annual Mean Concentrations and Total Discharge at Armstrong Slough South Watershed 83

V-12 Annual Mean Nitrogen and Phosphorus Export Rates from Armstrong Slough South Watershed 84

V-13 Time Series Concentrations-Peavine Pasture, Turbidity and P 86

V-14 Time Series Concentrations-Peavine Pasture, Color and Conductivity . . .87

V-15 Time Series Concentrations-Peavine Pasture, Inorganic and Total N . . .88

V-16 Time Series Concentrations-Peavine Pasture, Ortho and Total P 89

V-17 Annual Mean Concentrations and Total Discharge at Peavine Pasture . . .90

V-18 Annual Mean Nitrogen and Phosphorus Export Rates from Peavine Pasture . .92

V-19 Time Series Concentrations-Wildcat Slough East Watershed, Color and Turbidity 94

V-20 Time Series Concentrations-Wildcat Slough East Watershed, Conductivity and pH 95

V-21 Time Series Concentrations-Wildcat Slough East Watershed, Inorganic and Total N 96

V-22 Time Series Concentrations-Wildcat Slough East Watershed, Ortho and Total P 97

V-23 Annual Mean Concentrations and Total Discharge at Wildcat Slough East Watershed 98

V-24 Annual Mean Nitrogen and Phosphorus Export Rates from Wildcat Slough East Watershed 99

V-25 Time Series Concentrations-Wildcat Slough West Watershed, Turbidity and pH 100

V-26 Time Series Concentrations-Wildcat Slough West Watershed, Color and Conductivity 102

V-27 Time Series Concentrations-Wildcat Slough West Watershed, Inorganic and Total N 103

V-28 Time Series Concentrations-Wildcat Slough West Watershed, Ortho and Total P 104

V-29 Annual Mean Concentrations and Total Discharge at Wildcat Slough West Watershed 105

V-30 Annual Mean Nitrogen and Phosphorus Export Rates from Wildcat Slough West Watershed 106

V-31 Time Series Concentrations-Wildcat Slough Watershed, Conductivity and pH 107

V-32 Time Series Concentrations-Wildcat Slough Watershed, Color and Turbidity 108

V-33 Time Series Concentrations-Wildcat Slough Watershe Inorganic and Total N 110

V-34 Time Series Concentrations-Wildcat Slough Watershed, Ortho and Total P 111

V-35 Time Series Concentrations-Ash Slough East Watershed, Conductivity and pH 112

V-36 Time Series Concentrations-Ash Slough East Watershed, Color and Turbidity 114

V-37 Time Series Concentrations-Ash Slough East Watershed, Inorganic and Total N 115

V-38 Time Series Concentrations-Ash Slough East Watershed, Ortho and Total P 116

V-39 Annual Mean Concentrations and Total Discharge at Ash Slough East . . . 117

V-40 Annual Mean Nitrogen and Phosphorus Export Rates from Ash Slough East 118

V-41 Time Series Concentrations Ash Slough West Watershed, Conductivity and pH 119

V-42 Time Series Concentrations Ash Slough West Watershed, Color and Turbidity 120

V-43 Time Series Concentrations Ash Slough West Watershed, Inorganic and Total N 122

V-44 Time Series Concentrations Ash Slough West Watershed, Ortho and Total P 123

V-45 Annual Mean Concentrations and Total Discharge at Ash Slough West . . . 124

V-46 Annual Mean Nitrogen and Phosphorus Export Rates from Ash Slough West 125

V-47 Time Series Concentrations-SEZ Dairy, Conductivity and pH 127

V-48 Time Series Concentrations-SEZ Dairy, Color and Turbidity 128

V-49 Time Series Concentrations-SEZ Dairy, Inorganic and Total N 129

V-50 Time Series Concentrations-SEZ Dairy, Ortho and Total P 130

V-51 Annual Mean Concentrations and Total Discharge at SEZ Dairy 132

V-52 Annual Mean Nitrogen and Phosphorus Export Rates from SEZ Dairy . . . 134

V-53 Annual Export Rates and Mean Flow Weighted Concentrations of Dissolved Inorganic N in Runoff from Upland Demonstration Project Watersheds 108

V-54 Annual Export Rates and Mean Flow Weighted Concentrations of Total N in Runoff from Upland Demonstration Project Watersheds 138

V-55 Annual Export Rates and Mean Flow Weighted Concentrations of Ortho P in Runoff from Upland Demonstration Project Watersheds 139

V-56 Annual Export Rates and Mean Flow Weighted Concentrations of Total P in Runoff from Upland Demonstration ProjectWatersheds 140

V-57 Uptake Versus Loading Rates for Total N on UplandDemonstration Project Watersheds 142

V-58 Mean Total N Concentrations in Shallow GroundwaterVersus Total N Loading Rates on Upland Demonstration Project Watersheds 143

V-59 Mean Total N Concentrations in Shallow GroundwaterVersus Total N Loading Rates on Upland Demonstration Project Watersheds-Adjusted Version . . 145

V-60 Mean Shallow Groundwater Concentrations of Dissolved Inorganic N Versus Annual Surface Loading Rates 146

V-61 Total P Uptake Versus Loading on Upland Demonstration Project Watersheds 147

V-62 Michaelis Menten Curve and Equation 148

V-63 Monthly Flow Weighted Total N Concentrations in Runoff from Ash Slough Pastures 150

V-64 Monthly Flow Weighted Total P Concentrations in Runoff from Ash Slough Pastures 151

VI-1 Daily Inflow and Discharge at the Ash Slough Wetland During Event 1 157

VI-2 Time Series Concentrations of Total Nitrogen at the Ash Slough Wetland During Event 1 158

VI-3 Time Series Concentrations of Total Phosphorus at the Ash Slough Wetland During Event 1 159

VI-4 Daily Inflow and Discharge at the Ash Slough Wetland During Event 2 . . 161

VI-5 Time Series Concentrations of Total Nitrogen at the Ash Slough Wetland During Event 2 162

VI-6 Time Series Concentrations of Total Phosphorus at the Ash Slough Wetland During Event 2 163

VI-7 Daily Inflow and Discharge at the Ash Slough Wetland During Event 3 . . 165

VI-8 Time Series Concentrations of Total Nitrogen at the Ash Slough Wetland During Event 3 166

VI-9 Time Series Concentrations of Total Phosphorus at the Ash Slough Wetland During Event 3 167

VI-10 Daily Inflow and Discharge at the Ash Slough Wetland During Event 4 . . 170

VI-11 Time Series Concentrations of Total Nitrogen at the Ash Slough Wetland During Event 4 171

VI-12 Time Series Concentrations of Total Phosphorus at the Ash Slough Wetland During Event 4 172

VI-13 Daily Inflow and Discharge at the Ash Slough Wetland During Event 5 . .174

VI-14 Time Series Concentrations of Total Nitrogen at the Ash Slough Wetland During Event 5 175

VI-15 Time Series Concentrations of Total Phosphorus at the Ash Slough Wetland During Event 5 176

VI-16 Loading, Uptake, and Uptake Efficiencies for Nitrogen and Phosphorus in the Ash Slough Detention/Retention Wetland 179

VI-17 Time Series Concentrations at Major Inflows and Outfall Stations in the Arnmstrong Slough Wetland - pH and Turbidity 182

VI-18 Time Series Concentrations at Major Inflows and Outfall Stations in the Arnmstrong Slough Wetland - Color and Conductivity 183

VI-19 Time Series Concentrations at Major Inflows and Outfall Stations in the Arnmstrong Slough Wetland - Inorganic and Total Nitrogen 184

VI-20 Time Series Concentrations at Major Inflows and Outfall Stations in the Arnmstrong Slough Wetland - Ortho and Total Phosphorus 185

VI-21 Mean Annual Time Series and Flow Weighted Concentrations for Dissolved Inorganic Nitrogen at Inflow and Outfall Stations in Upland Demonstration Project Detention Wetlands 194

VI-22 Mean Annual Time Series and Flow Weighted Concentrations for Total Nitrogen at Inflow and Outfall Stations in Upland Demonstration Project Detention Wetlands 195

VI-23 Mean Annual Time Series and Flow Weighted Concentrations for Ortho Phosphorus at Inflow and Outfall Stations in Upland Demonstration Project Detention Wetlands 196

VI-24 Mean Annual Time Series and Flow Weighted Concentrations for Total Phosphorus at Inflow and Outfall Stations in Upland Demonstration Project Detention Wetlands 197

VI-25 Annual Uptake/Export Rates Versus Loading Rates of Total and Inorganic Nitrogen at the Armstrong and Ash Slough Wetlands 199

VI-26 Annual Uptake/Export Rates Versus Loading Rates of Total and Ortho Phosphorus at the Armstrong and Ash Slough Wetlands 200

VI-27 Total P Uptake Versus Loading on Selected Wetlands 206

LIST OF TABLES

		Page
I-1.	Upland Demonstration Project Sites - Land Uses	3
I-2.	Land Use Intensity of Upland Demonstration Project Study Sites	6
I-3.	Annual Total Rainfall on the Upland Demonstration Project Study Sites	9
I-4.	Mean Annual Time Series and Flow Weighted Concentrations at Armstrong Slough Marsh	16
I-5.	Mean Annual Time Series and Flow Weighted Concentrations at Ash Slough Marsh	17
I-6.	Ash Slough Marsh Mass Budgets	18
I-7.	Armstrong Slough Marsh Mass Budgets	19
I-8.	Comparison of Theoretical Nutrient Concentrations at the Armstrong Slough Marsh Outfall with Those Measured During the First-Flush Event of August 25 - September 23, 1981	24
I-9.	Annual Loading and Uptake Rates for Nitrogen and Phosphorus in the Ash and Armstrong Slough Wetlands 1979-1982	25
I-10.	Observed Ranges of Loading and Uptake Rates for Total N and Total P at Four Kissimmee River Basin Wetlands	28
IV-1.	Total Mean Annual Rainfall on Upland D/R Project Area - Historical Period of Record	52
IV-2.	Historical Mean Monthly and Annual Rainfall at Stations in the Vicinity of Upland Project Sites	53
IV-3a.	Monthly and Annual Rainfall on Upland Demonstration Project Sites: 1979-80	54
IV-3b.	Monthly and Annual Rainfall on Upland Demonstration Project Sites: 1980-81	54
IV-3c.	Monthly and Annual Rainfall on Upland Demonstration Project Sites: 1981-82	55
IV-4.	Rainfall Quality Data Summary	62
IV-5.	Concentrations of Selected Nutrient Species Reported in Precipitation	63
IV-6.	Typical Historical Loading Rates Attributed to Precipitation on Upland D/R Project Study Sites for Entire Period of Record	64
IV-7.	Precipitation Loading Rates for Selected Nitrogen and Phosphorus Species Reported in the Literature	65
IV-8a.	Annual Nutrient Loads Attributed to Rainfall on Upland D/R Project Sites: 1979-80	66

IV-8b. Annual Nutrient Loads Attributed to Rainfall on Upland D/R Project Sites: 1980-81 66

IV-8c. Annual Nutrient Loads Attributed to Rainfall on Upland D/R Project Sites: 1981-82 67

V-1. Upland Demonstration Project Sites - Land Uses 68

V-2. Annual Percentage Reduction of Nutrients and Flow for the Wildcat Slough Watershed as Measured at the Outfall to C41-A 109

V-3. Mean Percent Contribution of Nutrient Loads to the SEZ Dairy Watershed 133

V-4. Literature Values of Total N and Total P Export Rates in Nonpoint Runoff by Land Use 136

VI-1. Dates and Duration of Five Monitored Inflow/Discharge Events at Ash Slough Marsh 153

VI-2. Estimated Nutrient Loads and Water Volumes Contributed to the Ash Slough Marsh from Rainfall and Ungauged Runoff 154

VI-3. Water and Nutrient Budget for the Ash Slough Marsh Event #1 156

VI-4. Water and Nutrient Budget for the Ash Slough Marsh Event #2 156

VI-5. Water and Nutrient Budget for the Ash Slough Marsh Event #3 164

VI-6. Water and Nutrient Budget for the Ash Slough Marsh Event #4 169

VI-7. Water and Nutrient Budget for the Ash Slough Marsh Event #5 169

VI-8. Annual Water and Nutrient Budget Summary for Ash Slough 177

VI-9. Ash Slough Marsh Annual and Event Based Uptake-Efficiencies 178

VI-10. Armstrong Slough Marsh - Estimated Mean Monthly and Annual Detention Times (Days) with Depth 187

VI-11. Armstrong Slough Uptake Efficiencies 188

VI-12a Monthly Turnover Rates and Mean Residence Times for Flow Volumes Through the Armstrong and Ash Slough Wetlands 1979-80 191

VI-12b Monthly Turnover Rates and Mean Residence Times for Flow Volumes Through the Armstrong and Ash Slough Wetlands 1980-81 192

VI-12c Monthly Turnover Rates and Mean Residence Times for Flow Volumes Through the Armstrong and Ash Slough Wetlands 1981-82 193

VI-13. Reduction Efficiencies for Total N in Wetlands as Reported in the Literature 203

VI-14. Reduction Efficiencies for Total P in Wetlands as Reported in the Literature 204

SECTION I
EXECUTIVE SUMMARY AND CONCLUSIONS

BACKGROUND AND PROJECT DESCRIPTION

The Upland Detention/Retention Demonstration Project was conceived in 1976 by the Coordinating Council on the Restoration of the Kissimmee River Valley and Taylor Creek/Nubbin Slough Basin (KRVCC or Council) for the purpose of evaluating ". . whether the detention of runoff in the uplands and routing of waters through wetlands would be as cost effective and low energy design for significantly improving the water quality of flowing into Lake Okeechobee as is commonly believed. ." (McCaffrey et al, 1977). The study was funded by the Florida Legislature in June of 1977. The project was designed to meet two major goals. These were:

1. To refine the state of knowledge of water quality problems associated with agricultural runoff characteristic of the Kissimmee River Valley and Taylor Creek/Nubbin Slough Basin, and
2. To develop and evaluate pollution abatement practices one of which was detention/retention by natural and recreated wetlands.

As the plan of study was being developed, it became evident to Council staff that design, construction, and monitoring of such a project on five distinct sites would require a combination of engineering and scientific expertise and a variety of manpower capabilities. The South Florida Water Management District (SFWMD or District) was the only entity that had resources capable of providing the complete range of services necessary to meet these needs. The Council contracted with the District in September 1978 to provide five basic services. These were:

1. To design, construct, and maintain various weirs, flumes, levees, culverts, risers, and similar devices for the control of surface water movements at sites and locations identified by the Council.
2. To install and maintain various instruments required to acquire hydrological data necessary to compute volume and flow rate of surface waters at various locations selected by the Council.
3. To collect water samples for chemical and physical analyses.
4. To provide laboratory analytical services for the water quality samples.
5. To analyze and interpret water chemistry and hydrology data and to document the results in a series of oral and written reports.

In order to evaluate land use impacts on surface runoff quality, eight distinct watersheds on five separate project sites were chosen by the Council staff for the study. Attempts were made by the use of limited earth moving activity (plugs, interceptor ditches, tieback levees, etc.) to isolate each watershed hydrologically from those adjacent to it. Criteria for site selection were generally (1) homogeneity of land use at each specific site (all agricultural of various intensities), (2) ease of hydrological isolation, (3) ease of measuring flows, (4) accessability for routine water quality sampling, and (5) cooperation of the landowner. Locations of the five chosen sites are depicted in Figure I-1. The sites, watersheds, acreages, and land uses are listed in Table I-1.

To evaluate the ability of wetlands to function as effective low cost/low energy pollution abatement facilities, two distinct types of systems were selected for evaluation. The first was an existing 8.1 ha (20 acre) wetland situated on the study site designated as Ash Slough in Okeechobee County near Basinger. The wetland was a natural low-lying depression that held water on an intermittant basis. It experienced seasonal extremes of inundation and drought. The second wetland, located at the site designated Armstrong Slough in Osceola County was a 12.1 ha (30 acre) flow-through marsh created in what had once been part of the Kissimmee River floodplain but had subsequently been ditched, drained, and converted to improved pasture. The marsh was created by the efforts of District engineers and Resource Operations personnel who designed and constructed an earthen plug for the existing drainage channel in order to force water into a surrounding peripheral wetland. Unlike the Ash Slough wetland, this one remained continually inundated to various degrees throughout the course of this study.

The remainder of this section summarizes the District's activities in support of the Upland Demonstration Project for each of the areas for which contractual obligation existed. This section will conclude

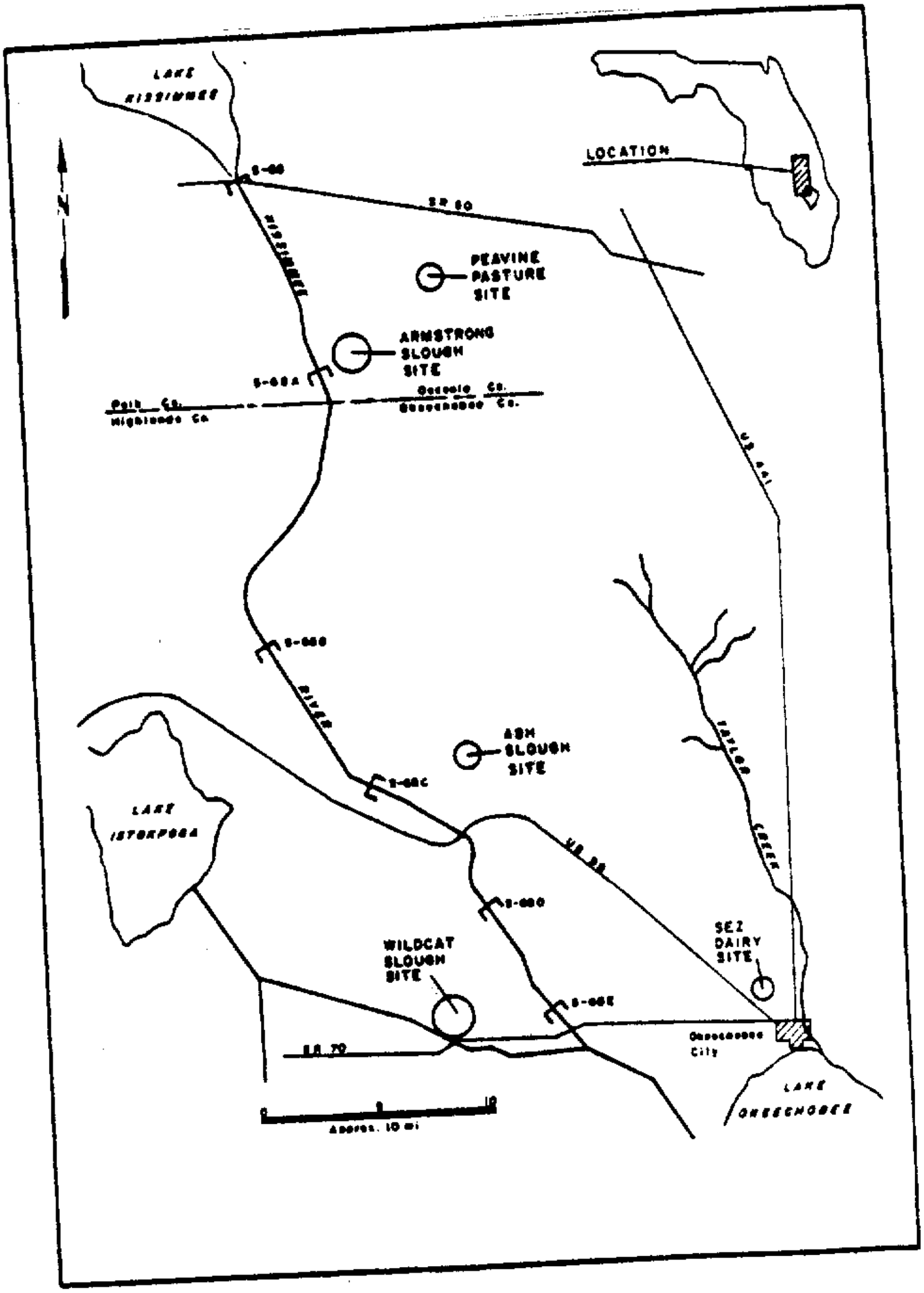


Figure I-1. General area and study sites for the Upland Detention/Retention Demonstration Project.

TABLE I-1. UPLAND DEMONSTRATION PROJECT SITES - LAND USES

Study Site	Watershed/Size (ha)	Predominant Land Use	Cattle Density Cows/Acre
Wildcat Slough	East Watershed (2591)	Native Range	.05
	West Watershed (1729)	Native Range	.05
Peavine Pasture	(243)	Improved Pasture	.20
Armstrong Slough	North Watershed (3036)	Improved Pastures, Citrus	.20
	South Watershed (1012)	Native Range Improved Pastures	.20
Ash Slough	East Watershed (20.2)	Improved Pasture	.33
	West Watershed (68.8)	Improved, Ditched Pastures	.33
SEZ Dairy	Holding Pasture (121.5)	Cattle Holding, Staging Area	1.63
	Hay Pasture (202.4)	Hay, Heifer Grazing	.40

conclude with a review of the major scientific findings and conclusions that resulted from these activities. The remainder of this report is divided into five sections, each of which provides an in-depth description of one aspect of the study. Section II provides a history of the project inception as well as detailed site descriptions. Section III describes general methods for hydrology and water quality monitoring analysis. Section IV contains an analysis of rainfall on the study area and its potential impacts in terms of natural background contributions of nutrients to these agricultural watersheds. Section V describes the watershed land use/runoff quality studies, and Section VI describes the wetland detention/retention evaluations. The appendixes (Volume II) contain monthly and annual nutrient materials budgets for each watershed and wetland in a tabularized fashion as well as summary data of land use/water quality relationships.

DISTRICT ACTIVITIES

CONSTRUCTION

Construction and preparation activities on the five sites ranged from as little as installation of a steel protective instrument housing at SEZ Dairy to major earth moving and structure installation at Armstrong Slough to create a wetland. Details of these activities are documented in the annual reports prepared by SFWMD staff (1979), Goldstein et al (1980), and Goldstein and Ulevich (1980). Activities required at each site were as follows:

Wildcat Slough: Construction of a concrete critical depth flume (six foot throat) and associated tieback levee in order to concentrate flow for purposes of obtaining more accurate flow measurements.

Peavine Pasture:
(1) Construction of a concrete V-notch critical depth flume and associated tieback levee for measurement of flows leaving the site.

(2) Installation of a sand plug at a point in a major drainage channel where the natural watershed boundary was judged to occur. This insured that flow generated from outside the watershed was not measured at the monitoring site.

Armstrong Slough:

(1) Installation of six new 72 inch CMP culverts with associated risers and flashboard control structures in the main drainage channel at Armstrong Slough under the access road to S65-A on the C-38 canal. This was judged to be necessary due to the poor condition of the existing culverts and the desire to insure that there was adequate flow capacity to prevent a washout of the associated access road. Sheet pile wingwalls to prevent erosion and a catwalk to provide access were installed contiguous to the culvert structures.

(2) A concrete critical depth flume for flow measurements and an associated tieback levee were installed across the southern tributary watercourse. The initial sizing of the flume throat (3 feet) proved to be inadequate to deal with extreme high flows. This device was replaced by a larger structure with a 5 foot throat.

(3) In May of 1980, a major modification of the site was accomplished by plugging the primary drainage channel and constructing flow diver-sion levees and ditches to create flow through the wetland. The plug and diversion levees (Figure I-2) occupied roughly 1,200 feet of the old channel and began approximately 500 yards upstream of the outfall culverts under the S65-A access road.

Ash Slough:

(1) A tieback levee containing two 40 foot-18 inch diameter CMP culverts with flashboard and riser structures was constructed at the downstream end of the existing wetland. These were used to control water level and measure flow leaving the marsh.

(2) A large concrete V-notch critical depth flume was constructed in the major drainage ditch that conveyed water from a large area of extensively ditched pasture.

(3) An interceptor ditch (approximately 18 inches deep) was dug along the eastern edge of the wetland to collect sheet flow runoff from an adjacent pasture and a smaller concrete V-notch critical depth flume was constructed in the outlet ditch leading into the marsh.

(4) An earthern plug was installed in a ditch that connected two large ditched pasture blocks thus isolating the far one from contributing flow to the marsh. Small culverts were installed under the access road to the site in order to convey surface drainage away from the subject watershed.

(5) A wooden shelter was constructed at the marsh outfall and 110 volt electrical power was provided so that an automatic water sampling device with a refrigerated storage compartment could be installed.

SEZ Dairy: No earthwork or flow control structures were required at SEZ Dairy. Vandalism of instrumentation at the site outfall, however, dictated the installation of a bullet-proof, lockable shelter for stage recorders and automatic sampling devices. The steel shelter was suspended across the drainage channel on two 9 inch steel I-beams and stabilized by the use of cross braces between the beams and 1/4 inch steel cables running from the top of the shelter to anchors in the ground. The shelter was vented and supplied with an exhaust fan and 110 volt electrical power receptacles so that an automatic water sampling device with a refrigerated storage compartment could be installed.

HYDROLOGY

Culverts, flumes, and tieback levees referenced in the previous section were all constructed and installed to make possible collection of flow data at each site. These flow data were obtained indirectly through the use of the flow control structures, available water stage data, and application of the appropriate flow equation for the type of outflow structure (flume or culvert). Instantaneous flow rates were mathematically calculated for water levels recorded on digital stage recorders at 30 minute intervals. These recorders were installed, calibrated, and maintained by District personnel. The 48 instantaneous flow measurements obtained at each site over a 24 hour period were multiplied by the corresponding time interval (30 minutes) and summed to yield daily flow measurements. Twenty of these stage recorders were installed in such a manner that flow measurements could be obtained at twelve stations on the five project study sites. Each recorder was serviced monthly throughout the study period. Over the three year course of the study, these recorders were responsible for over 50,000 individual flow measurements at each monitoring station.

WATER QUALITY SAMPLING

Surface water samples were collected for quality analysis on both a routine biweekly basis at each site and on a storm event basis at two of the sites (Ash Slough and SEZ Dairy). Collection of water quality data began in April of 1979 and continued through the end of September 1982. During this three and one-half years, over 4,200 water samples were

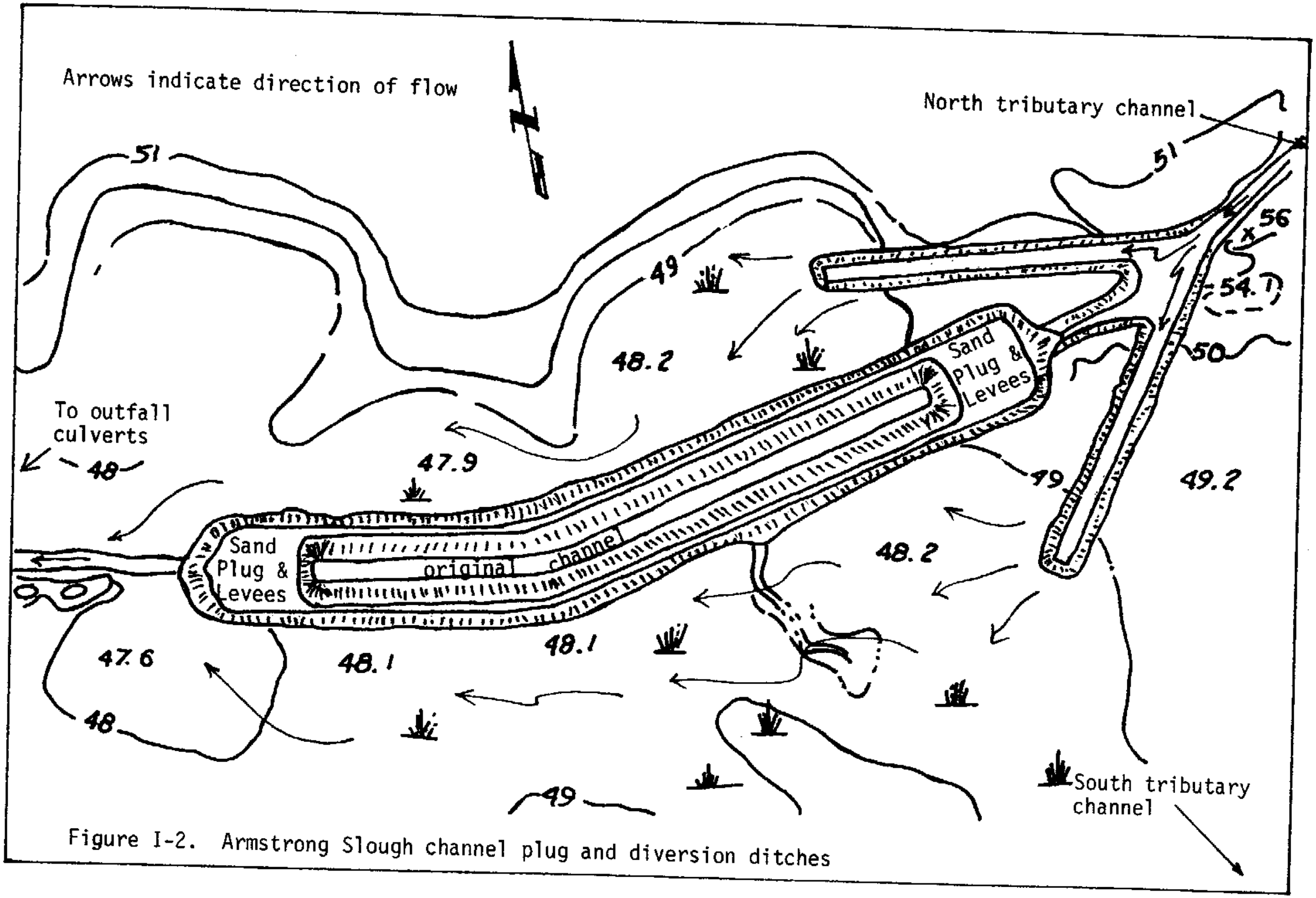


Figure I-2. Armstrong Slough channel plug and diversion ditches collected at 19 stations on the five sites and analyzed for pH, turbidity, conductivity, and color as well as nitrogen and phosphorus species concentrations. Installation of flow monitoring equipment lagged behind the commencement of water quality sampling at most sites and thus, materials budgets which required both flow and quality data were calculated for the three year period of record October 1, 1979 through September 30, 1982.

LABORATORY

A laboratory facility was set up in the city of Okeechobee for the express purpose of providing analytical support for this project. The 2,400 square foot facility (Figure I-3) included areas for digestion and analysis of water samples as well as a field preparation laboratory. In addition, office and storage space were provided for the project management and field staff. The laboratory was constructed in the fall of 1978. During the study, a portion of the facility was sublet to the Florida Game and Freshwater Fish Commission to house personnel working on related projects on the Upland Demonstration Project sites and elsewhere in the Kissimmee River Basin. Detailed descriptions of analytical techniques, equipment, and procedures are contained in Goldstein et al (1980).

DATA INTERPRETATION AND REPORTS

District scientific personnel were responsible for interpreting and reporting the results of the data collected throughout the course of the project. Project progress and preliminary results were documented in writing on annual or semi-annual bases by the production of five reports to Council prepared as District Technical Memoranda distributed over the subject time period. In addition, annual formal project progress updates were presented orally at Council meetings as well as at annual Demonstration Project contractor meetings held by Council staff. In addition, preliminary results have been presented at formal gatherings including several scientific symposia, the Florida Academy of Sciences, and the Florida Range Management Society.

RESULTS

LAND USE/WATER QUALITY IMPACTS

Land use on the eight watersheds of the five study sites was solely agricultural dedicated predominantly to various intensities of cattle production. The intensity of use ranged from the native range - unimproved pasture at the Wildcat Slough site - to an intensive dairy operation near the city of Okeechobee. Land use intensity was measured in two different ways - the first was in terms of numbers of animals per unit land surface area (cows per acre), the second was by amount of nutrient loading (nitrogen and phosphorus) applied per unit surface area (kg/ha) of the subject watershed. Nutrient loading was estimated or measured from all known sources (rainfall, fertilizer application, etc.) for each individual watershed. Table I-2 contains the rank order of the land use intensity of the eight watersheds from least to most intense.

Annual rainfall during the three year study period at the five study sites was characterized as

TABLE I-2. LAND USE INTENSITY OF UPLAND DEMONSTRATION PROJECT STUDY WATERSHEDS

Watershed	Cows/Acre	Estimated Annual Loading Rate	
		Kg/ha Total N	Kg/ha Total P
Wildcat Slough - East and West	0.05	13.5	0.8
Ash Slough - East	0.33	14.1	0.9
Armstrong Slough - South	0.20	58.9	11.5
Peavine Pasture	0.20	94.1	22.5
Armstrong Slough - North	0.20	199.5	21.3
Ash Slough - West	0.33	81.6	34.6
SEZ Dairy	1.63	264.0	52.9

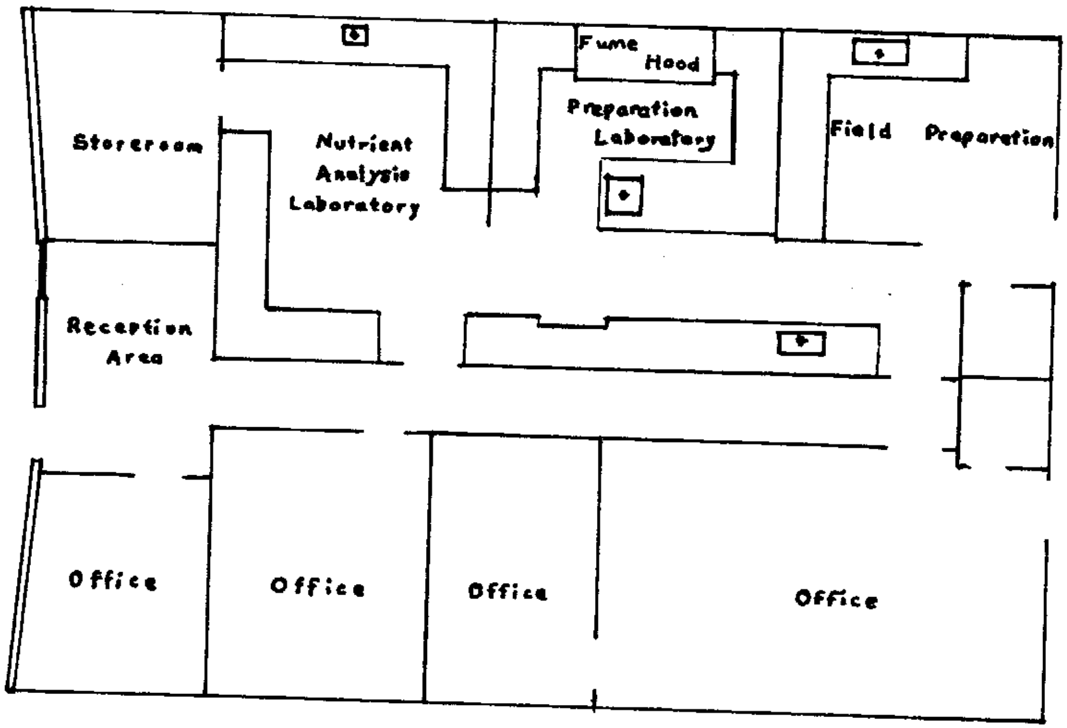


Figure I-3. Floor plan of Okeechobee Environmental Research Center.

"below normal" ranging from as little as 57 cm (22 inches) at Peavine during the first year of the study to 141 cm (55.4 inches) at Armstrong Slough during the last year of study (Table I-3). Total monthly rainfall was less than historical averages during 20 or more of the 36 months study period at each of the five sites. Measured monthly rainfall at Peavine pasture was less than the historical average during 30 of the 36 months. Only at one site (Armstrong Slough) during the final year of study did an annual rainfall total exceed the historical average.

Minimum, maximum, and mean concentrations for the time series of nitrogen and phosphorus data collected at the five sites over the three year study period are graphically depicted in Figures I-4 and I-5. Annual mean flow weighted concentrations are also indicated. The major difference between nitrogen and phosphorus was that nitrogen concentrations consistently exhibited more variation but responded less to intensity of land use than was the case with phosphorus concentrations. At land use intensities characteristic of dairy operations, mean annual concentrations (both time series and flow weighted) of nitrogen species are greater than at those sites where lesser numbers of animals per unit land area were kept.

Phosphorus concentrations (both ortho and total) were also impacted at land use intensities (P-loading rates) experienced at Ash Slough-west and SEZ Dairy. This was reflected as increases in the range of maximum concentrations experienced as well as increases in mean time series and flow weighted concentrations. This impact is best illustrated by a plot of mean annual export rates versus mean annual loading rates for the study sites (Figure I-6). Loading rates less than 25 kg P/ha per year do not appear to have significant impact on the amounts of phosphorus exported from these watersheds. Loading rates above this level do, however, appear to have significant impact on export rates of phosphorus. The P export rate at Ash Slough-west, loaded at about 35 kg P/ha per year, is ten times greater than the P export rate of watersheds loaded at 22 kg P/ha per year. Of interest to note is that as these watersheds are loaded increasingly heavier with phosphorus, the absolute amount of P taken up by the watershed tends to increase, but the percentage of load applied that is retained by the watershed decreases. For example, the Armstrong Slough-north watershed retained 20.8 kg (98.8 percent) of the estimated P load while the Ash Slough-west and SEZ Dairy watersheds retained about 29.6 and 40.0 kg respectively (only about 86-87 percent).

Phosphorus loading on the dairy watershed occurs continuously on a year-round basis due to its addition as a supplement to feed for dairy cattle. Each milk cow is fed roughly .09 kg (0.2 lbs.) of phosphorus each day. This has been found to be the optimum amount necessary to insure good continuous milk production and animal health. Unassimilated P deposited on the land surface of the pasture appears to be a major source of P contributions in runoff from this dairy. It is estimated that this source accounted for 54 percent of the total P load on the dairy watershed during this study. This importation of P to the watershed and its subsequent deposition on the ground surface in animal feces has been and will continue to be one of the primary sources of P contamination in runoff from these watersheds.

The second major source of P in runoff from these watersheds appears to be from fertilizer application to improved pastures. This is most readily apparent when comparing flow weighted concentrations over time at the two Ash Slough watersheds, one of which was fertilized during the study period and one which was not (Figure I-7). Runoff from the eastern unfertilized watershed was consistently low in P concentrations. Runoff from the western fertilized watershed had exceedingly high P concentrations during periods of rainfall even three or more months after application. Concentrations typically decreased during the year throughout the wet season as the applied P was continuously leached from the water-shed. Concentrations late in the summer eventually approached those typical of the adjacent unfertilized watershed. While fertilizer application was the primary source of the P load on the Ash Slough-west pasture, it was estimated to have constituted roughly 40 percent of the total P load on the SEZ Dairy watershed.

It has been widely believed that the major contribution of P from dairy activity was due to discharge from the wastewater lagoons that receive and hold the milking barn washwater. This study suggests that a reasonably well maintained and operated lagoon system actually contributes only a very small portion of the total P load (this was estimated to be only about 3 - 4 percent at SEZ Dairy) exported from these dairy watersheds. It can be argued that since 90 - 95 percent of the P loading on the watershed is either via manure deposited on the ground surface, fertilizer, or a combination of both, that these sources are most likely the major contributors. The behavior of P in runoff from the Ash Slough-west watershed after fertilizer application lends credence to this view as P export from that watershed where there are no lagoons or dairy cows approaches export rates characteristic of the dairy.

TABLE I-3. ANNUAL TOTAL RAINFALL ON UPLAND DEMONSTRATION PROJECT STUDY SITES

Location	Estimated Historical Mean Annual Rainfall Centimeters	Year 1 1979-80 Centimeters	(% of Mean)	Year 2 1980-81 Centimeters	(% of Mean)	Year 3 1981-82 Centimeters	(% of Mean)
Armstrong	126.75	92.4	(73)	96.0	(76)	140.8	(111)
Ash	113.70	106.1	(93)	72.5	(64)	99.8	(88)
Peavine	126.75	57.0	(45)	71.3	(56)	118.2	(93)
SEZ	137.45	87.8	(64)	96.3	(70)	125.0	(91)
Wildcat	117.22	73.8	(63)	86.9	(74)	102.8	(88)

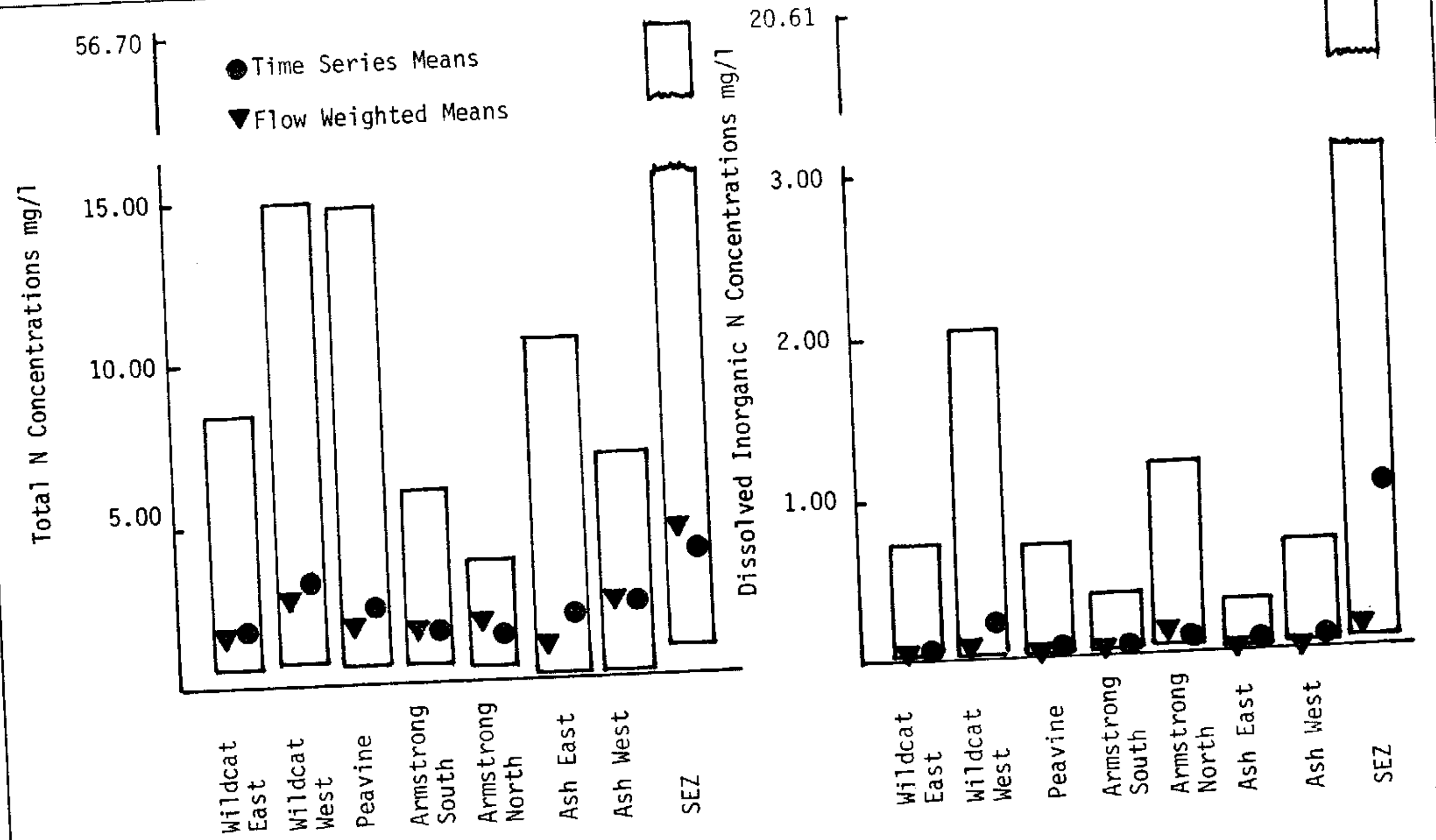


Figure I-4. Means and Ranges of Total and Dissolved Inorganic Nitrogen Concentrations in Runoff from Upland Demonstration Project Sites.

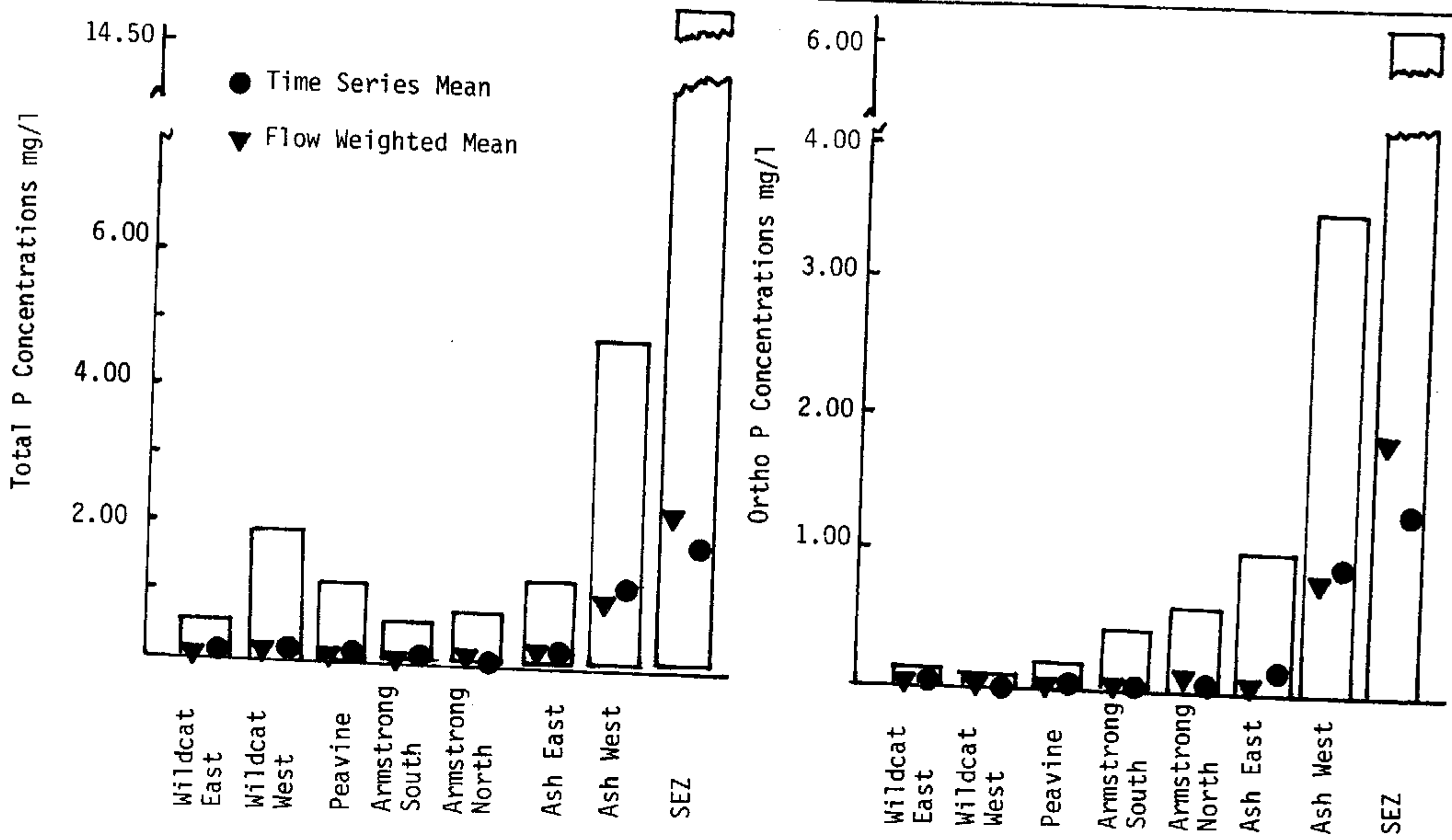


Figure I-5. Means and Ranges of Total and Ortho Phosphorus Concentrations in Runoff from Upland Demonstration Project Sites.

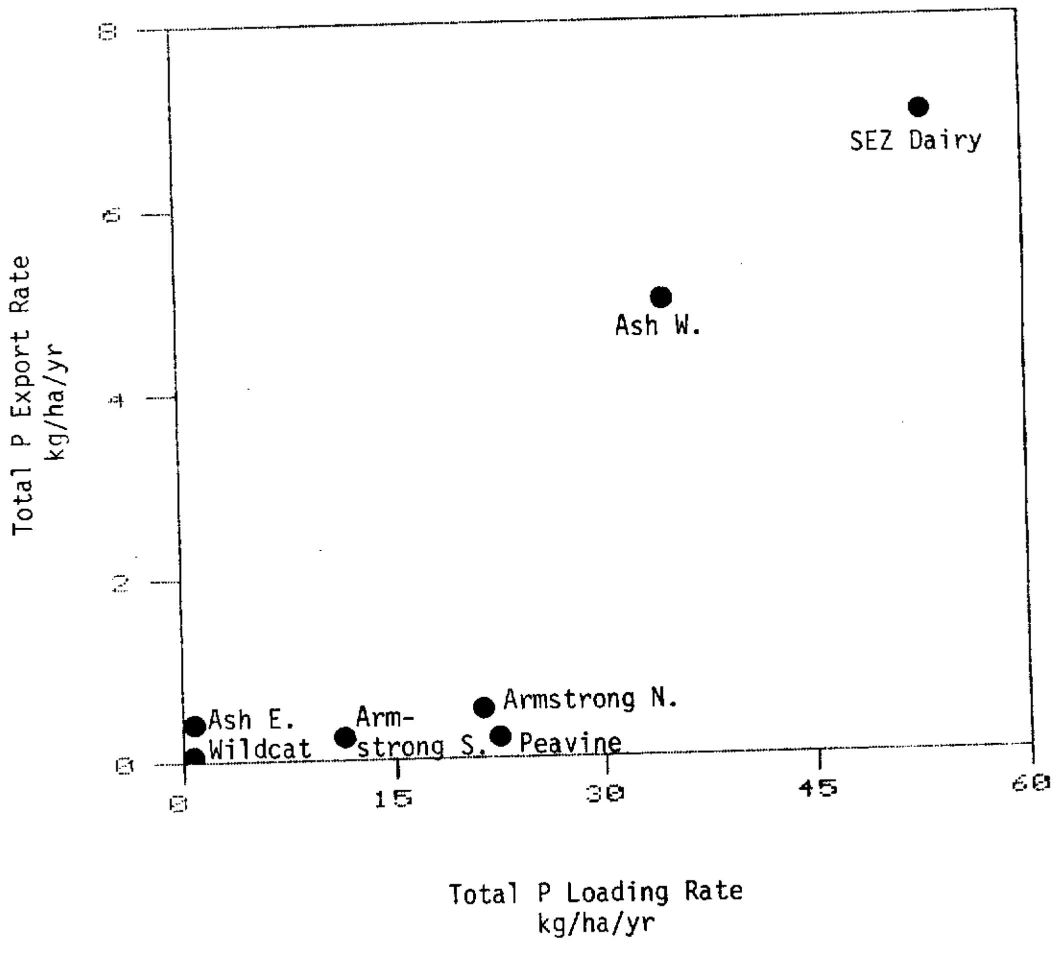


FIGURE I-6. MEAN ANNUAL PHOSPHORUS EXPORT VERSUS LOADING RATES ON UPLAND DEMONSTRATION PROJECT WATERSHED.

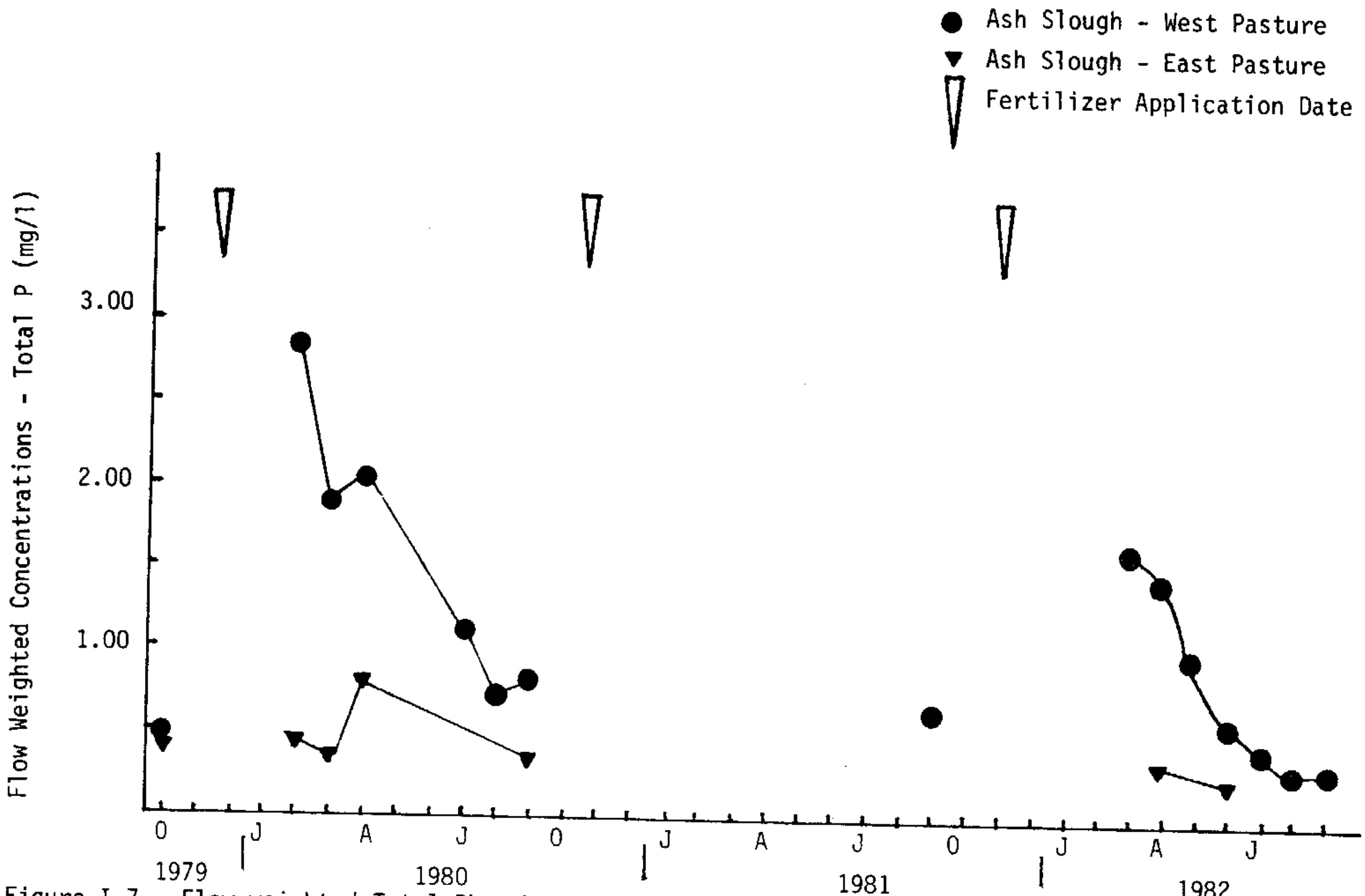


Figure I-7. Flow weighted Total Phosphorus concentrations in runoff from pastures at Ash Slough.

The most probable mechanism of P export from these watersheds appears to be deposition on the ground surface and subsequent movement through shallow lateral subsurface flow or surface runoff when it occurs during periods of rainfall long and/or intense enough to saturate the soil.

The Armstrong Slough watersheds responded to the end of the 1981 drought with a typical "first-flush" in August - September accompanying the onset of runoff from a series of rainfall events. This first flush was manifest as increases in N and P concentrations which subsided to pre-flush levels after about six weeks. This phenomenon was not apparent on any of the other study sites.

In summation, the following conclusions can be drawn about land use/intensity versus nonpoint source runoff water quality:

1. Neither total nitrogen concentrations in runoff nor export rates tend to be influenced to any great degree by the types of land uses (cattle) typical of these watersheds.
2. Phosphorus concentrations in runoff and export rates from these watersheds do appear to be influenced by the magnitude of P load applied to the watershed. At the dairy and on improved pasture where culturally applied loads exceeded 23 kg P/ha per year, P export rates increased significantly. The ability of the watershed to absorb P (absolute quantities) seemed to increase with increased loading but the percentage of uptake of the applied load declined.
3. The major source of P in runoff from these watersheds is from sources external to the watershed, but which are transported in and culturally applied. These are dairy feed rations and fertilizers on hay and grazing pastures.
4. Discharge from a moderately well maintained and operated dairy barn washwater lagoon contributes only a very small portion (less than 5 percent) of the total P export from this dairy watershed.

WETLANDS AS DETENTION/ RETENTION FACILITIES

Wetlands have been touted as natural filter systems capable of "cleansing" water by removing pollutants typically carried in surface stormwater runoff. This study was designed to test whether or not this hypothesis holds true for wetlands and runoff from agricultural lands in the Kissimmee River basin.

Pollutants associated with agricultural runoff in other parts of the country (suspended sediment, pesticides, herbicides, etc.) are not of any real significance in runoff from watersheds and land uses typical of the Kissimmee basin. The primary materials of interest are the nutrient species (nitrogen and phosphorus) which, when found in runoff, are associated with accelerating the eutrophication process of the ultimate receiving waters (in this case Lake Okeechobee).

Specific objectives of the Upland Demonstration Project study as it pertained to wetlands were:

1. To compare and contrast two different types of wetlands used as detention/retention facilities.
2. To quantify the nutrient removal capacity of each system.
3. To compare the efficiency of those wetland systems against reported efficiencies of other wetlands.

The two wetlands located at the Ash and Armstrong Slough study sites were similar in that their surfaces were characterized by a permanent community of wetland vegetation species and the surrounding land use was basically the same, being improved pasture utilized for grazing unconfined livestock (predominantly cattle).

Differences between the two systems were quite notable however. The most significant was the nature of the wetland hydrological regimes. The Ash Slough marsh experienced periods of inundation interrupted by periods when the marsh would essentially dry out and become devoid of standing surface waters. This wetland received pulses of water on an intermittent basis associated with periods of rainfall or lack of same. Over the course of this study, five distinct inundation periods or "events" occurred. The Armstrong Slough marsh, by contrast, received water from at least one tributary year-round and was continually inundated.

The Ash Slough marsh existed in a natural low area that had remained essentially undisturbed, even though the fields around it had been cleared and planted with pasture grasses. The Armstrong Slough marsh was situated in an original riverine backwater area that, upon channelization of the Kissimmee River, had been drained and converted to improved pasture. Only a small portion of the original wetland existed when, during the course of the project, the drainage channel was plugged and the wetland enlarged to its present size.

The surface area of the Ash Slough wetland was estimated to cover approximately 8.1 ha (20 acres) and the surface area of Armstrong Slough was approximately 12.1 ha (30 acres). Mean depth at Ash Slough probably rarely exceeded 0.15 m (0.5 feet) while at Armstrong Slough mean depth rarely exceeded 0.46 m (1.6 feet).

Given the surface areas and mean depths, the Armstrong Slough wetland was estimated to cover 1.5 times more surface area than Ash Slough and to have approximately 4.8 times more storage volume. Total annual hydraulic loading at Ash Slough for the three years were only 7.1, 0.6, and 2.4 percent of those measured at Armstrong Slough. The Armstrong Slough wetland, while only half again as large in surface area and 4.8 times as large in volume, received annually from 14 to 166 times more water than did Ash Slough and as such, detention times were significantly less and the ratio of marsh substrate surface area per unit volume of water to be treated was less.

One other notable difference between the two sites was the nature and use of the adjacent pastures. The watersheds contributing runoff to the Ash Slough marsh were characterized by more intense drainage ditch density and more intense fertilizer application practices. Thus, while subjected to lesser volumes of runoff than Armstrong Slough, it was normally loaded with higher concentrations of N and P such that total loads applied to the wetlands were more nearly equal. On a per unit surface area basis, mass loads of inorganic N at Armstrong Slough were 3.5 to 7.5 times greater than at Ash, while total N loads were 5 to 14 times greater. By contrast ortho P and total P loads per unit surface area were usually greater at Ash Slough by 1.2 to 2.4 times.

Mean annual time series and flow weighted concentrations of N and P species in inflow and discharge at Armstrong and Ash Sloughs are listed in Tables I-4 and I-5. As a rule, both flow weighted and time series concentrations in inflows and discharges were less at Armstrong than at Ash Slough.

With the exception of total and ortho P concentrations during the final year of the study, both time series and flow weighted concentrations were consistently reduced in the discharge from the Armstrong Slough marsh. At Ash Slough on the other hand, concentrations of both N and P species were often higher at the discharge station than in the inflows.

Annual water and nutrient budgets for the Ash and Armstrong Slough marshes are presented in Tables I-6 and I-7. Notable features are that in almost all cases both wetlands were net nutrient retainers. The sole exception was for total N and P species during the final year at Armstrong Slough. The net export during that year was the result of two factors. The first was an artifact of the surface water budget which for that year was calculated to consist of almost 10 percent more discharge than measured inflow from all surface sources. It is speculated that additional water could conceivably have been contributed from groundwater seepage into the marsh since soil saturation conditions during that year were such that this phenomenon would be a plausible explanation. The second factor was that the concentrations of total N and P during that year were either only slightly reduced in the wetland (as was the case for the former) or actually increased (as was the case for the latter).

Reduction of mass nutrient load was considered to be either "passive" (an amount of reduction equal to the percentage of water loss in the wetland due to evaporation, seepage, or storage) or "active" uptake (the amount of reduction that exceeded the percent water loss/storage in the system). Comparison of uptake on this basis indicates that on an annual basis, dissolved nutrient species (inorganic N and ortho P) are consistently being actively removed by both wetlands. Active uptake of total N, however, was not as consistent. At Armstrong Slough percent uptake barely exceeded percent water loss/storage during the first two years and during the last year was actually less than percent water loss/storage. In this wetland, uptake of total N was essentially of a passive nature associated with what would be expected by loss/storage alone.

At Ash Slough total N uptake was substantially less than that expected through passive uptake mechanisms. While the dissolved portion of the total N load is actively removed it comprises only a small percentage of the total N load (7 to 8 percent during the two more normal rainfall years). Therefore, in order to have an impact on total N removal the marsh has to trap and remove quantities of particulate N material. While the wetlands may be doing this, they are simultaneously (through internal cycling) producing similar material through vegetative detritus that is subject to being flushed from the system when a suitable mechanism (flow/discharge) occurs. These wetlands, therefore, appear to be in somewhat of a steady state condition with respect to active uptake and removal of nitrogen. Whatever loss occurs can be attributed almost solely to that associated with passive uptake through water loss/storage in the system.

Dissolved reactive (ortho) P uptake by these wetlands was generally of an active nature. Total P

TABLE I-4. MEAN ANNUAL TIME SERIES AND FLOW WEIGHTED CONCENTRATIONS AT ARMSTRONG SLOUGH MARSH
mg/L

	1979-80		1980-81		1981-82	
	Time Series	Flow Weighted	Time Series	Flow Weighted	Time Series	Flow Weighted
Dissolved Inorganic N						
Inflow Station 2	.06	.10	.21	.21	.08	.08
Inflow Station 3	.05	.05	.03	.06	.09	.02
Discharge Station 1	.03	.03	.02	.08	.05	.03
Total N						
Inflow Station 2	1.18	1.53	1.24	2.64	1.65	1.65
Inflow Station 3	1.71	1.44	1.59	2.41	2.04	1.34
Discharge Station 1	1.16	1.28	1.08	2.46	1.50	1.47
Ortho P						
Inflow Station 2	.032	.061	.069	.280	.034	.024
Inflow Station 3	.012	.013	.037	.055	.023	.011
Discharge Station 1	.022	.022	.042	.187	.038	.020
Total P						
Inflow Station 2	.084	.137	.116	.401	.085	.055
Inflow Station 3	.083	.056	.087	.129	.083	.045
Discharge Station 1	.061	.062	.069	.271	.089	.063

(consisting of ortho and particulate forms) uptake was slightly less efficient than ortho P uptake but was also generally of an active nature. Unlike the dissolved component of the total N load, ortho P was the significant portion of the total P load comprising 41 to 68 percent of the total P in inflow at Armstrong Slough and 73-85 percent of the total P load at Ash Slough. The reduction in percent uptake of total P as compared to ortho P indicates that either particulates are not as actively removed as dissolved forms or, due to internal cycling in the marsh, particulate forms are exported at a rate roughly comparable to that at which they are imported and trapped in the wetland.

In summary, reduction of nutrient loads in surface runoff by these wetlands appears to be achieved by a combination of loss/storage associated with water loss/storage and active uptake of dissolved forms. Particulate forms (particularly N) are either less actively removed or regenerated within the wetland by internal cycling. In some cases, particulate forms can be exported from the wetlands in quantities exceeding those in the inflows.

Time series plots of physical and chemical parameters at the outfall site at Armstrong Slough are depicted in Figures I-8 through I-11. During the course of the study, three distinct events occurred which had an impact on concentrations of one or more of these parameters. The first event was construction of the earthen plug in the channel upstream of the outfall and conversion of the peripheral upland area to a flow-through wetland. This event occurred during April and May of 1980. The actual construction activity seemed to impact only turbidity values as a distinct sharp increase, coinciding with the onset of

TABLE I-5. MEAN ANNUAL TIME SERIES AND FLOW WEIGHTED CONCENTRATIONS AT ASH SLOUGH MARSH
mg/L

	1979-80		1980-81		1981-82	
	Time Series	Flow Weighted	Time Series	Flow Weighted	Time Series	Flow Weighted
Dissolved Inorganic N						
Inflow Station 2	.06	.04	.09	0	.17	.08
Inflow Station 4	.03	.08	.05	0	.05	0
Discharge Station 1	.11	0	.20	0	.20	.12
Total N						
Inflow Station 2	2.03	2.07	2.90	0	3.00	2.75
Inflow Station 4	1.78	1.93	2.28	3.07	2.23	2.24
Discharge Station 1	3.03	2.14	4.66	4.10	3.90	1.78
Ortho P						
Inflow Station 2	1.102	1.07	.551	.68	.904	.72
Inflow Station 4	.271	.29	.277	-	.121	.11
Discharge Station 1	.902	.73	2.112	0	1.024	.49
Total P						
Inflow Station 2	1.272	1.25	.751	.68	1.116	.85
Inflow Station 4	.384	.38	.425	-	.236	.15
Discharge Station 1	1.120	.87	2.251	0	1.249	.64

construction, was followed by a distinct and rapid decrease at the cessation of the activity upon completion of the project. A slight increase in dissolved inorganic N (NO_x + NH_4) occurred during this time.

The major impact of plug installation, for the first year at least, appeared to be a marked decrease in the variability as well as a lessening of the concentrations of N and P and turbidity. Other physical parameters appeared to remain unaffected.

It could be argued that the observed decreases in variability and magnitude of concentrations at the site outfall were as much a result of the record south Florida drought which occurred during 1980 and 1981 as they were of plug installation and conversion to wetland. Concentrations at the upstream stations after plug installation, however, remained fairly consistent in magnitude with those observed prior to plug installation so that apparent decreases in concentrations and variability (particularly total P) appear to be explained by creation of the wetland and the resulting increased residence time and substrate contact provided by the wetland.

The second notable event during this study was the sudden increase of nutrient concentrations in runoff from the watershed as a response to the onset of significant rainfall in August-September of 1981 which essentially ended the drought conditions that had existed prior to that time. A "first flush" was observed, manifested as rapid increases in both N and P concentrations from the watersheds (Figure 1-10 and 1-11). The N was essentially in particulate form while the P species were predominantly dissolved.

TABLE I-6. ASH SLOUGH MARSH MASS BUDGETS

	Mass In	Mass Out	Net Removal	% Removal
Water Budget (m^3)				
1979-80	546,383	364,824	181,558	33.2
1980-81	58,557	0	58,557	100.0
1981-82	665,153	499,645	165,505	24.9
Inorganic N (kg)				
1979-80	89.9	16	73.9	82.2
1980-81	38.2	0	38.2	100.0
1981-82	98.6	60	38.6	39.1
Total N (kg)				
1979-80	1,085	782	303	27.9
1980-81	95.3	0	95.3	100.0
1981-82	1,426.3	1,374	52	3.6
Ortho P (kg)				
1979-80	479	268	211	44.0
1980-81	5.3	0	5.3	100.0
1981-82	409	247	162	39.5
Total P (kg)				
1979-80	563	317	246	43.7
1980-81	7.3	0	7.3	100
1981-82	488	322	166	34.1

During this event that lasted throughout the month of September, the wetland attenuated flows of 27.4 percent through water loss/storage. In addition, flow-weighted concentrations of dissolved inorganic N, total N, ortho P, and total P was reduced by 60.0, 9.8, 22.1, and 23.5 percent, respectively, over theoretically expected concentrations had no active reduction occurred within the marsh (Table I-8). It appears that the wetlands functioned during this high flow, first flush event to reduce nutrient loads between the various inflows and the outflow point of the marsh. Roughly half of the phosphorus load reduction could be attributed to that associated with water loss/storage in the marsh, while the other half of the P load reduction could be attributed to a 23.5 percent reduction in flow weighted concentration between those observed and those expected had no uptake or loss occurred. Similarly, the major portion of the reduction of dissolved inorganic N load was estimated to be due to active chemical and biological processes rather than from seepage and hydraulic storage. Total N load reduction was more a result of seepage/storage than concentration reduction through biogeochemical processes.

The third event of significance was a hard freeze that occurred at Armstrong Slough during late January and early February 1982. Prior to this time, weather patterns had been such that freezing conditions, if they existed at all, were rather mild and short lived. The early 1982 event was an exception. Concentrations of dissolved inorganic N, ortho P, and total P responded with increases followed by decreases

TABLE I-7. ARMSTRONG SLOUGH MARSH MASS BUDGETS

	Mass In	Mass Out	Net Removal	% Removal
Water Budget (m^3)				
1979-80	7,691,953	3,186,527	4,505,426	58.6
1980-81	10,175,053	7,129,132	3,045,921	29.9
1981-82	28,046,032	30,679,769	-2,633,757	-9.4
Inorganic N (kg)				
1979-80	681	95	586	86
1980-81	1,719	592	1,127	93.9
1981-82	1,554	765	789	50.8
Total N (kg)				
1979-80	11,676	4,069	7,607	65.2
1980-81	25,812	17,552	8,260	32.0
1981-82	42,940	45,188	-2,248	-5.2
Ortho P (kg)				
1979-80	418	70	348	83.3
1980-81	2,292	1,335	957	41.7
1981-82	635	612	23	3.6
Total P (kg)				
1979-80	950	198	753	79.2
1980-81	3,386	1,930	1,456	43.0
1981-82	1,546	1,934	-388	-25.1

to concentration levels characteristic of those measured prior to the event. Total N concentrations increased at the time of the freeze but subsequently remained consistently high from that point on until the end of the study. There was no concurrent increase in these parameters at the inflow station in the northern tributary during this same period. Therefore, the observed rise can most likely be attributed to events within the marsh itself, particularly the decaying of aquatic vegetation killed by the freeze. Phosphorus (both ortho and total) appeared to be the nutrient species most impacted by the event. The freeze did not appear to impact any of the physical parameters except perhaps color which began to increase in February and continued to rise through the summer.

In the absence of rainfall - runoff events, discharges from the marsh were minimal during this period so the resulting phosphorus load exported was comparatively small. This might not have been the case had the freeze been followed by a wet period sufficiently intense to generate a substantial volume of flow from the marsh.

Given the differences in flow volumes and concentrations of N and P entering the two wetlands, the Armstrong Slough marsh was loaded with inorganic N at a rate of 3.5 to 7.5 times more per hectare surface area than was the Ash Slough marsh; however, total N loads were 5 to 14 times more per unit area (Table I-9). By contrast, ortho P and total P loads per unit surface area were usually greater at

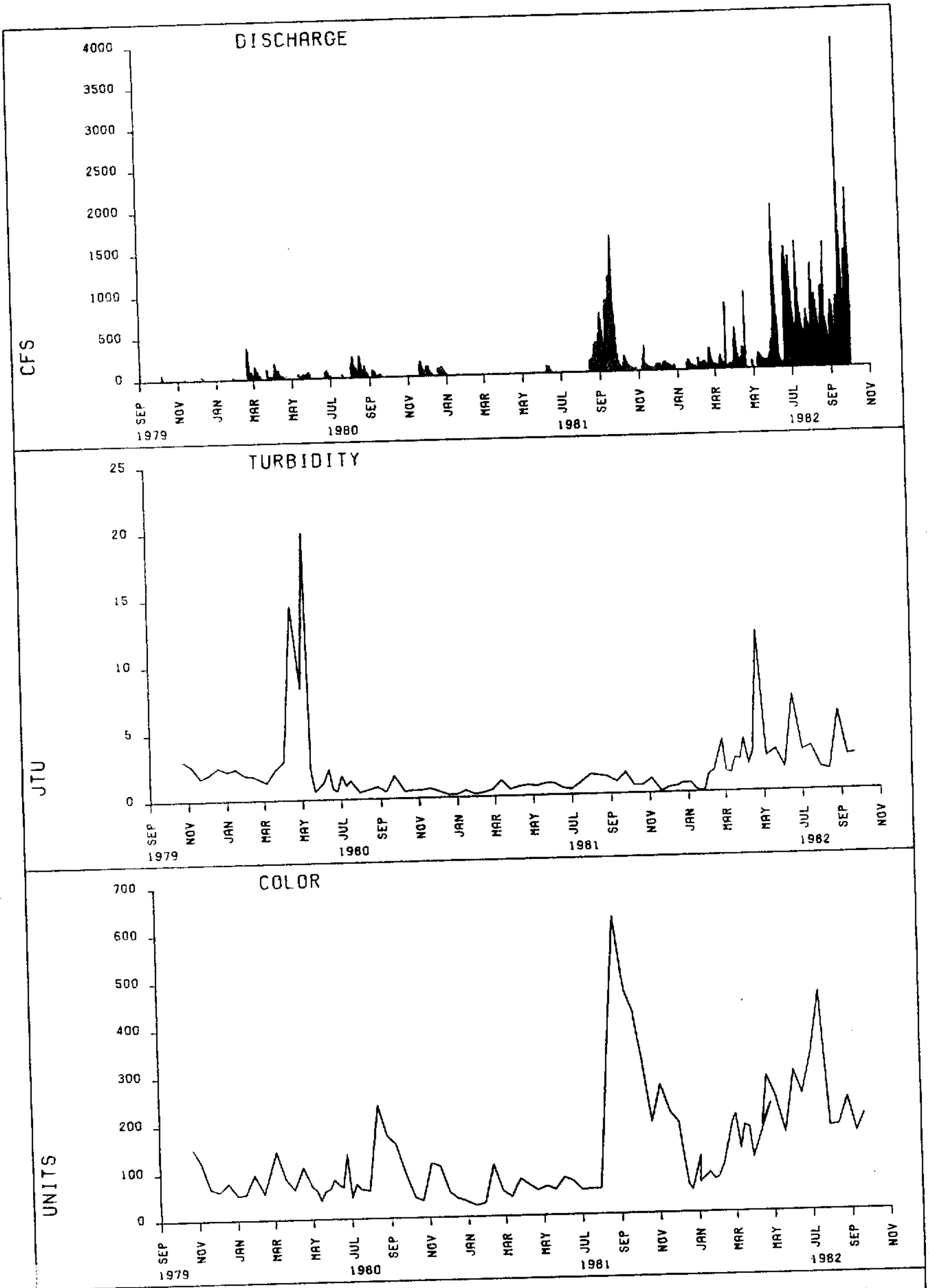


Figure I-8. Time Series Concentrations Armstrong Slough (1979-1982)-Station 1.

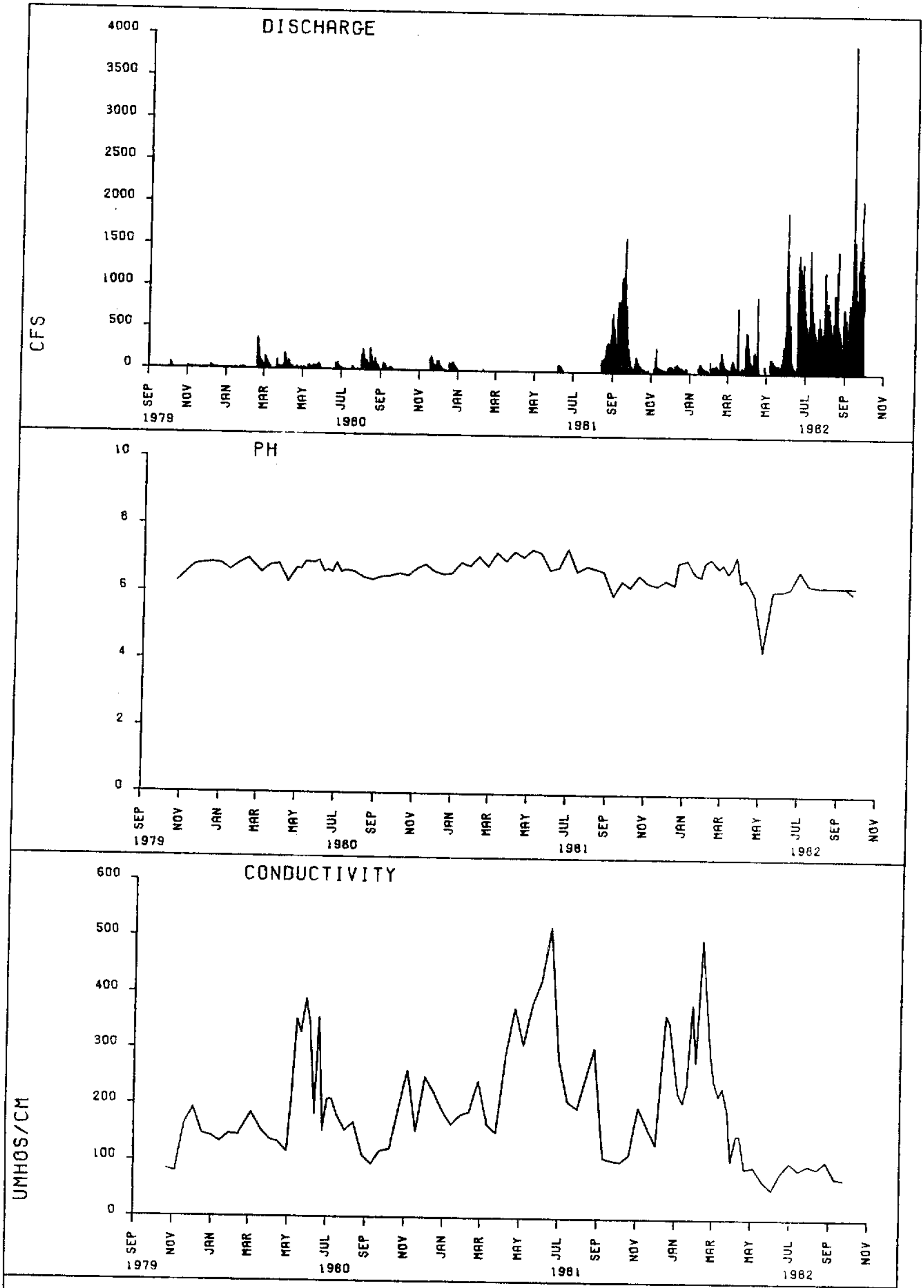


Figure I-9. Time Series Concentrations Armstrong Slough (1979-1982)-Station 1.

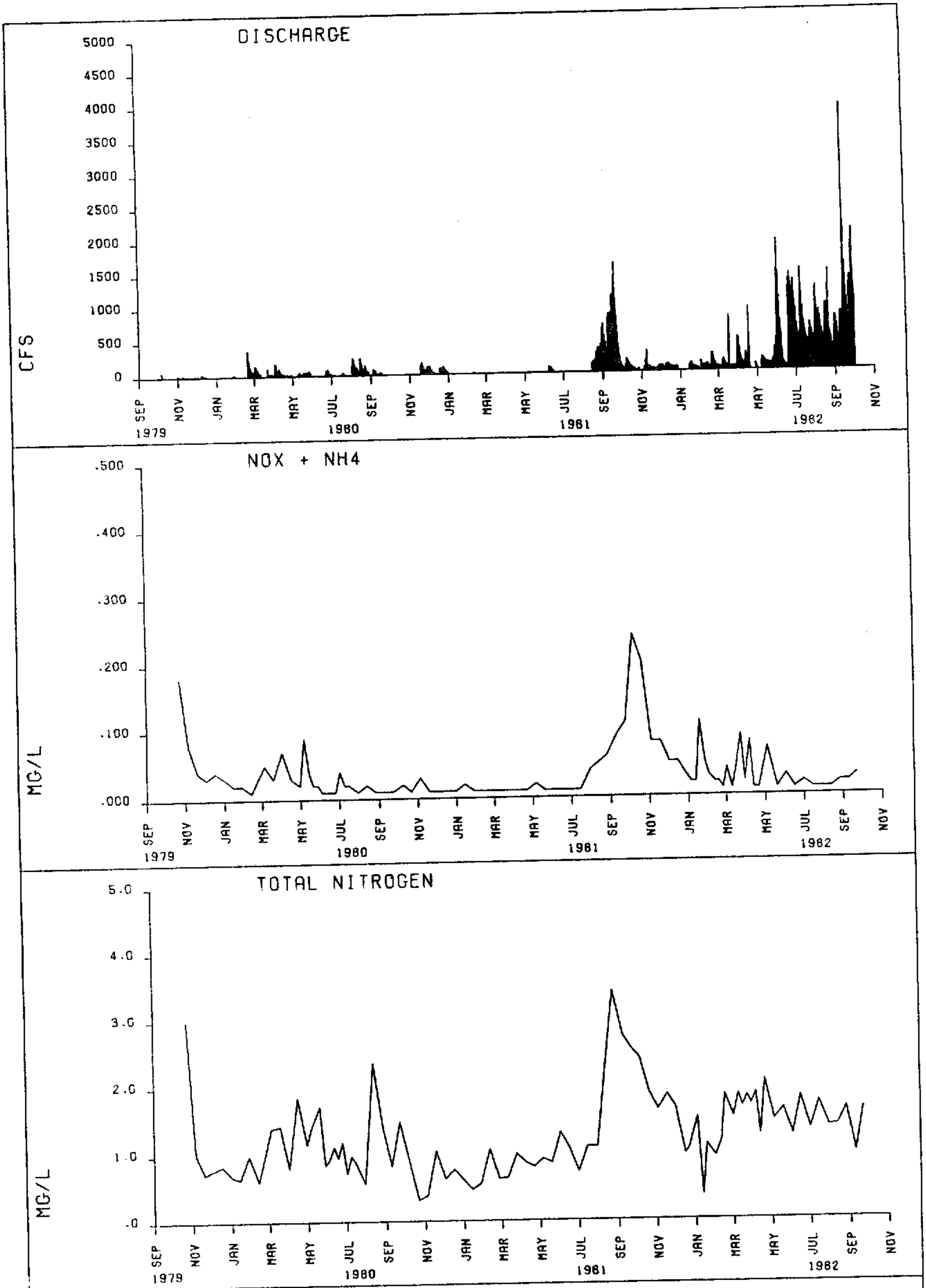


Figure I-10. Time Series Concentrations Armstrong Slough (1979-1982)-Station 1.

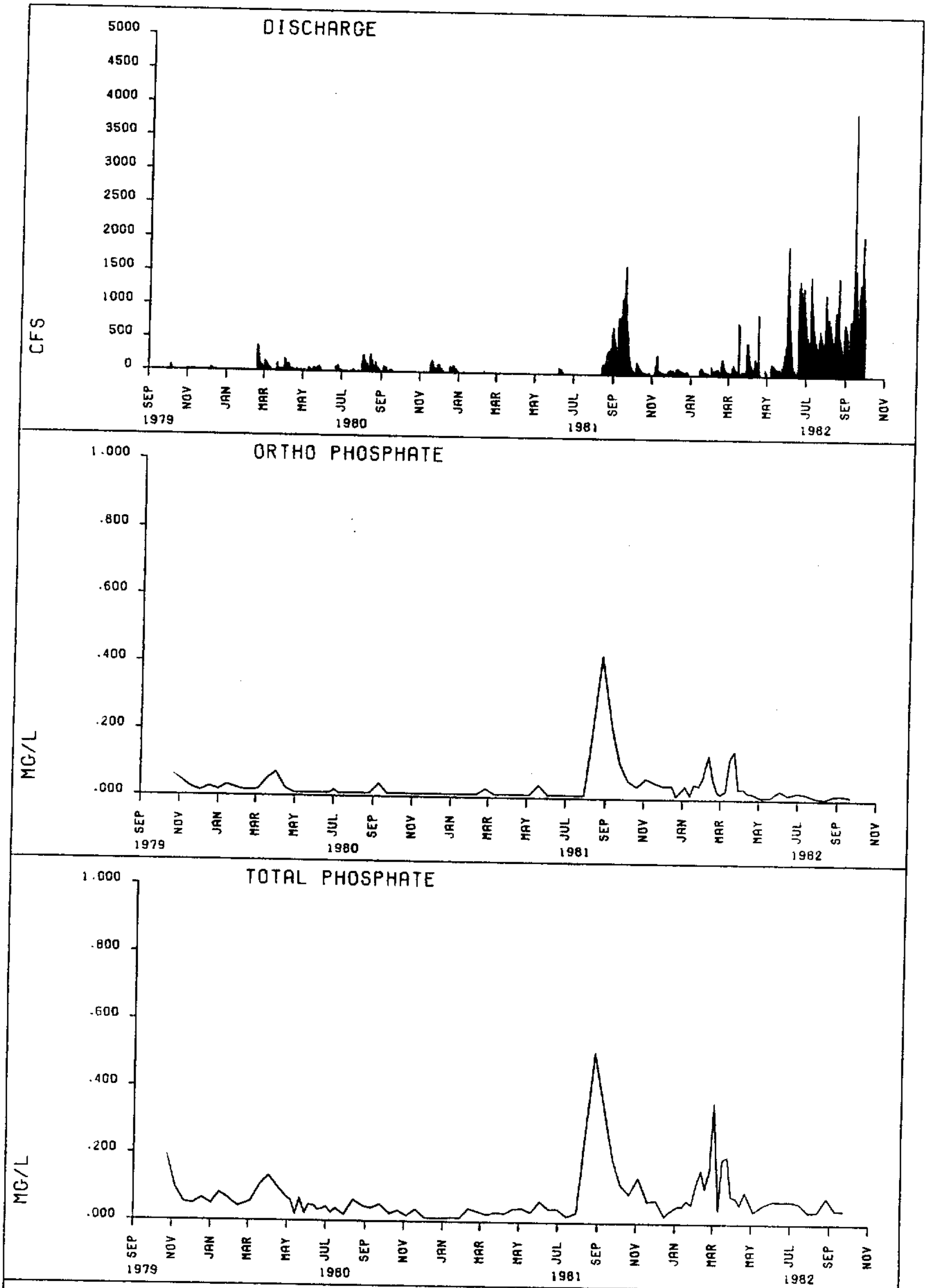


Figure I-11. Time Series Concentrations Armstrong **Slough** (1979-1982)-Station 1.

TABLE I-8. COMPARISON OF THEORETICAL NUTRIENT CONCENTRATIONS (mg/L) AT THE ARMSTRONG SLOUGH MARSH OUTFALL WITH THOSE MEASURED DURING THE FIRST-FLUSH EVENT OF AUGUST 25 - SEPTEMBER 23, 1981

Parameter	Theoretical Expected Flow Weighted Concentrations at Outfall Station	Observed Flow Weighted Concentrations at Outfall Station	Percent Reduction
Disolved Inorganic N	.209	.092	60.0
Total N	3.088	2.785	9.8
Ortho P	.289	.225	23.5
Total P	.426	.326	27.4
Flows (m^3)	7,112,797	5,162,772	27.4

Ash Slough by factors of 1.2 to 2.4 times. Only during the last year of the study, when flow volume into the Armstrong Slough wetland was comparatively large, was the marsh surface phosphorus loaded at a greater rate (1.5 times) than that which occurred at Ash Slough.

Net annual nutrient uptake or export rates in Table I-9 were plotted against annual mass loading rates. These data are depicted in Figures I-12 and I-13. Efficiency isopleths indicate that the wetlands consistently remove dissolved inorganic N at efficiency rates of greater than 50 percent even at the highest loading rates. By contrast, annual total N (which exists predominantly in particulate form) uptake efficiencies are consistently low, being greater than 50 percent only during the first year at Armstrong Slough. In each successive year subsequent, the efficiency of uptake in the Armstrong marsh continued to decrease until the wetland surface became a net exporter during the final year of study.

Ignoring the second year when abnormally dry conditions existed at Ash Slough, total and ortho P loading and uptake rates were relatively constant. Efficiency of annual uptake for P species at Armstrong Slough followed the same trend as noted for total N, decreasing each year regardless of the loading rate.

Whether this decrease in nutrient uptake efficiency is a reflection of the new wetland gradually approaching steady-state or just an artifact of the hydraulic regimes which occurred over the study period is uncertain. It is likely that as the wetland community matures, the potential active sites for soil uptake and vegetative growth become limited (lack of suitable substrate, available light, etc.) and senescence and decay rates begin to nearly equal growth and uptake rates. If this is occurring at Armstrong, then steady-state for N and P uptake was reached within three years of the wetland's creation. Should this be the case, future net nutrient reduction in the wetland would be due almost entirely to mechanisms associated with seepage and hydraulic storage.

The efficiency of nutrient uptakes by these marshes can be compared with those observed during investigations conducted at other locations in the south central Florida area, notably Chandler Slough (Federico et al, 1978) and Boney Marsh (Davis, 1981). Table I-10 contains a comparison of the range of loading and uptake rates for total N and P observed at each of those study sites. Concentrations at the inflows and outflow at Armstrong Slough are similar to those noted at these other Kissimmee basin wetlands. Due to the nature of the hydraulic loading per unit surface area, however, total N loading rates are an order of magnitude greater than those calculated for Ash Slough, Chandler Slough, or Boney Marsh. The Ash Slough wetland was loaded at a rate more comparable to Chandler Slough and the flow through portion of Boney Marsh. Uptake efficiency decreased over time but rates fell within the ranges characteristic of the other Kissimmee basin wetlands.

Phosphorous uptake efficiency appears to be highly dependent on flow regimes. Predominantly palustrine wetlands such as the Boney Marsh no-flow system and Ash Slough can theoretically experience 100 percent uptake during years when no discharges occur as was the case at Ash Slough during the

TABLE 1-9. ANNUAL LOADING AND UPTAKE RATES FOR NITROGEN AND PHOSPHORUS IN THE ASH AND ARMSTRONG SLOUGH WETLANDS 1979-1982 kg/ha/yr

	Inorganic N		Total N		Ortho P		Total P	
	Loading Rate	Uptake Rate	Loading Rate	Uptake Rate	Loading Rate	Uptake Rate	Loading Rate	Uptake Rate
Ash Slough								
Year 1	15.8	13.0	190.4	53.2	84.0	37.0	98.8	43.2
Year 2	6.7	6.7	16.7	16.7	0.9	0.9	1.3	1.3
Year 3	17.3	6.8	250.2	9.1	71.7	28.3	85.6	29.2
Armstrong Slough								
Year 1	56.7	48.8	973	634	34.9	29.0	79.2	62.7
Year 2	143.3	93.9	2,151	688	191.0	79.7	282.1	121.3
Year 3	129.5	65.7	3,578	-187	52.9	1.9	128.9	-32.3

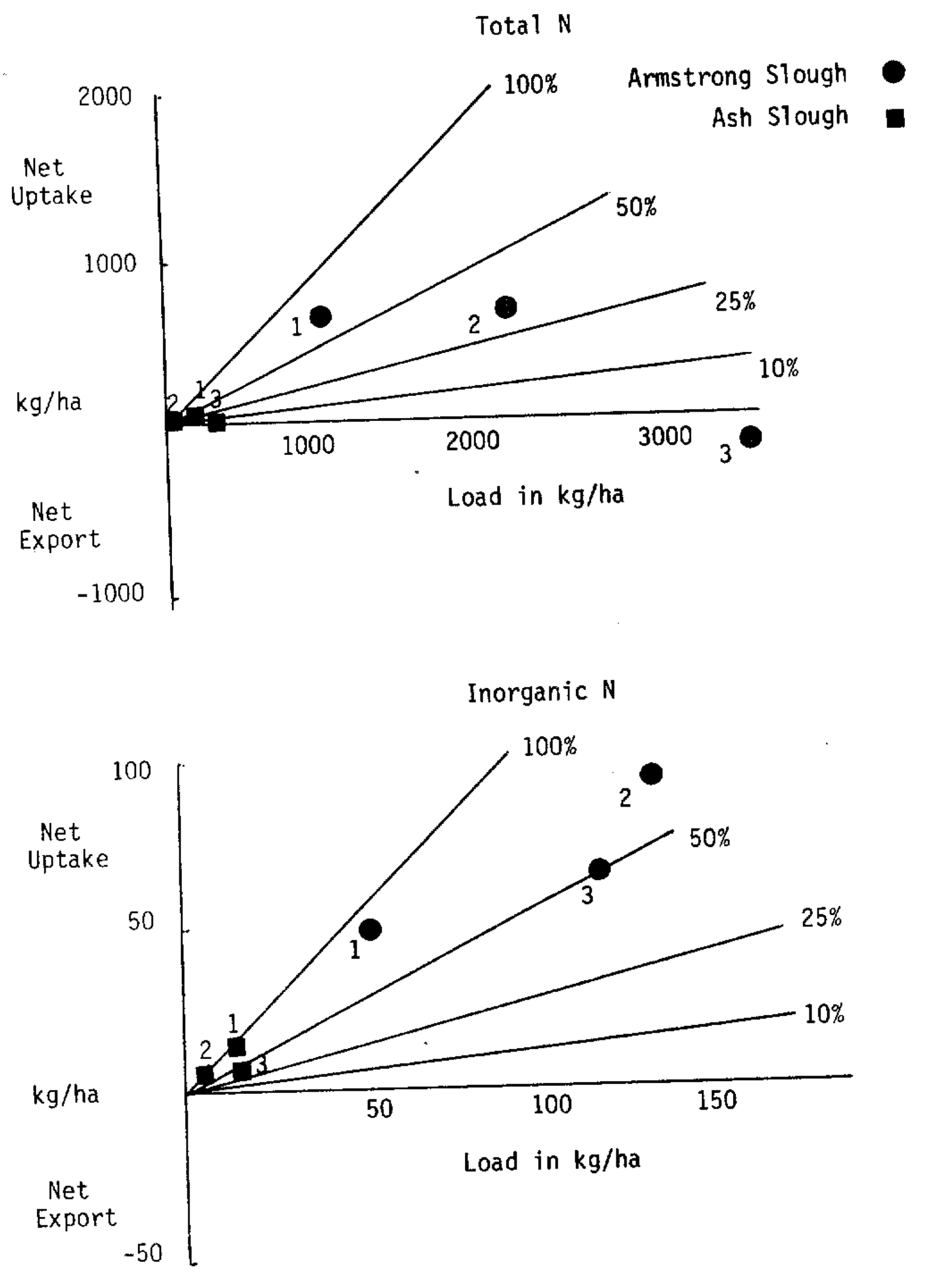


Figure I-12. Uptake/export versus loading rates for nitrogen in Upland Demonstration Project detention/retention wetlands.

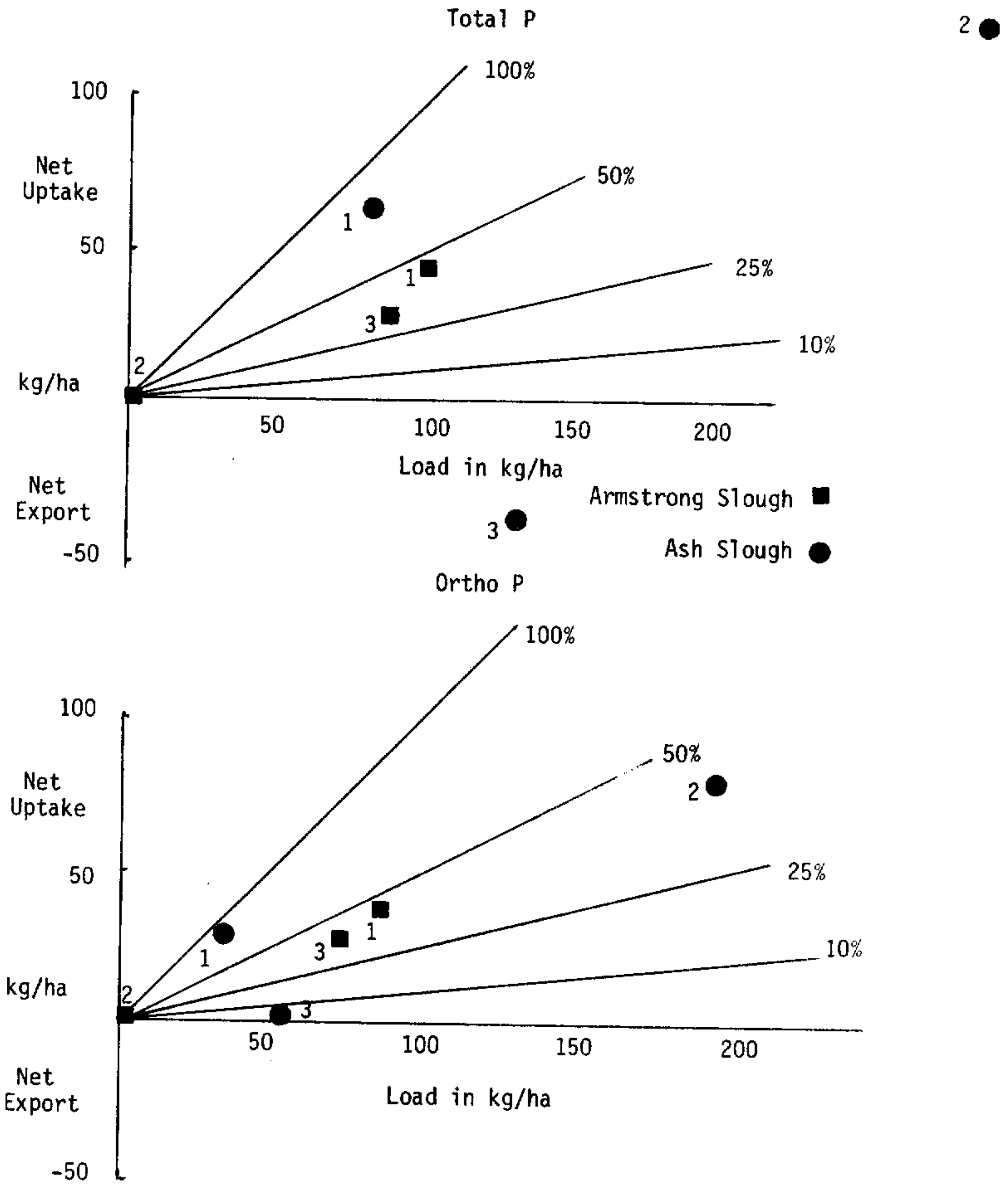


Figure I-13. Uptake/export versus loading rates for phosphorus in Upland Demonstration Project detention/retention wetlands.

TABLE I-10. OBSERVED RANGES OF LOADING AND UPTAKE RATES FOR TOTAL N AND TOTAL P AT FOUR KISSIMMEE RIVER BASIN WETLANDS (kg/ha/yr)

	Total N		Total P	
	Loading Rate	Uptake Rate	Loading Rate	Uptake Rate
Ash Slough*	190.4 - 250.2	9.1 - 53.2	85.6 - 98.8	29.2 - 43.2
Armstrong Slough	973 - 3,578	-187 - 688	79.2 - 282.1	-32.3 - 121.3
Chandler Slough	197 - 203.9	-9.6 - -1.6	37.6 - 51.9	4.2 - 16.0
Boney Marsh	38.6 - 167.9	31.3 - 39.9	2.3 - 6.1	2.1 - 4.3

*Ash Slough Data for Year Two Omitted

1980-81 season. Increasing loads may result in increased uptake rates, yet the efficiency of uptake may be less. Efficiencies tend to decrease as discharge volumes approach inflow volumes.

Regardless of differences in incoming concentrations and loading rates, with few exceptions these wetlands consistently exhibited phosphorus uptake efficiencies between 25 and 50 percent. These data are depicted in Figure I-14. Armstrong Slough during the first year had a much greater uptake efficiency but during the final year had a negative efficiency which was attributed in part to the hydrological regime that occurred during that year.

Increases in uptake rates given greater loading rates are probably the result of physical-chemical equilibria that exist between soil bound P and concentrations in the overlying water column. Where concentrations in the water column are higher than those in the soil, absorption phenomena tend to occur, though the efficiency may decrease with increasing loading rates. In the case of these Kissimmee basin wetlands, uptake efficiencies seem to remain between 25 to 50 percent.

In conclusion, the Ash and Armstrong Slough wetlands appear to function in much the same way as the other Kissimmee River basin wetlands in terms of their ability to remove N and P. They all appear to exist in near steady state equilibrium with respect to total N. They also seem to function at about the same level of eficiency as P sinks (below 50 percent). There is ample documentation in the literature that wetlands eventually reach steady-state conditions when absorptive capacity for P is spent. There is evidence that the efficiency of P uptake by the wetlands in this study (especially Armstrong Slough) is decreasing.

As a final note, the question arises as to how well wetlands function to remove N and P as compared to native range or improved pasture. While addressing this question was not an original goal of this study, the data obtained concurrently on the upland pastures and in the wetlands provide the opportunity to gain insight into the answer to this question.

Figures I-15 and I-16 are plots of annual uptake rates versus annual loading rates of total N and total P for the eight major agriculutral watersheds and two wetlands monitored during this study. Reported loading and uptake rates at Chandler Slough and Boney Marsh are also included to complete the comparison of comparative uptake efficiencies.

In the case of total nitrogen, the calculated or reported loading rates for all but one of the wetlands were within the range of magnitude of N loading rates estimated for upland pastures and dairies. The sole exception was Armstrong Slough which was loaded at a much heavier rate (4-14 times) than the other pastures and wetlands, thus it can be argued that this site is not directly comparable. In each of the other cases, however, uptake rates in pastures are at or nearly equivalent to the applied loading rate. The wetlands, on the other hand, consistently exhibited much poorer performance with uptake rates usually being substantially lower than loading rates. The best comparisons exist at loading rates of about 200 kg/ha/yr. The Armstrong Slough-north and SEZ

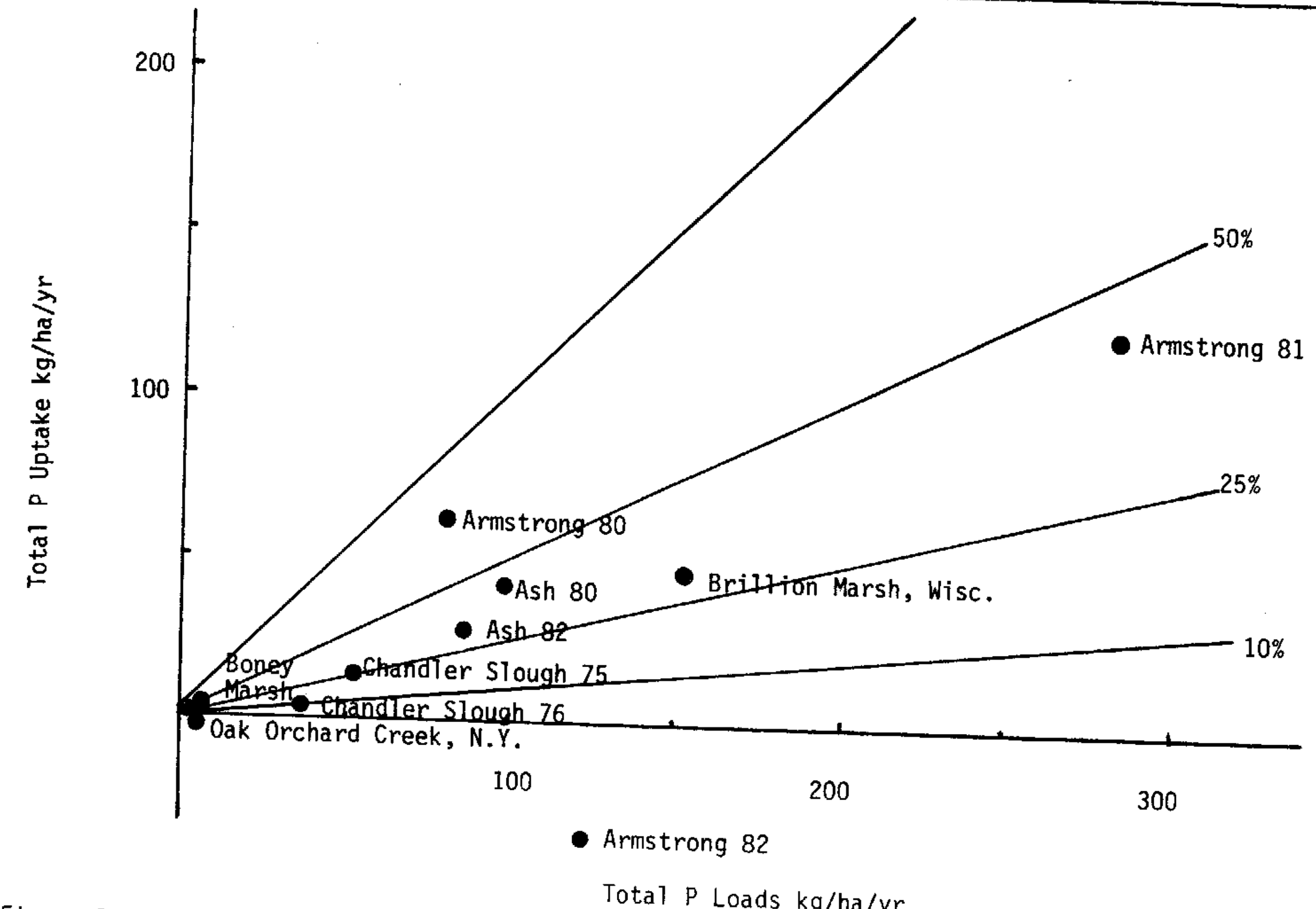


Figure I-14. Total P uptake verses loading on selected wetlands.

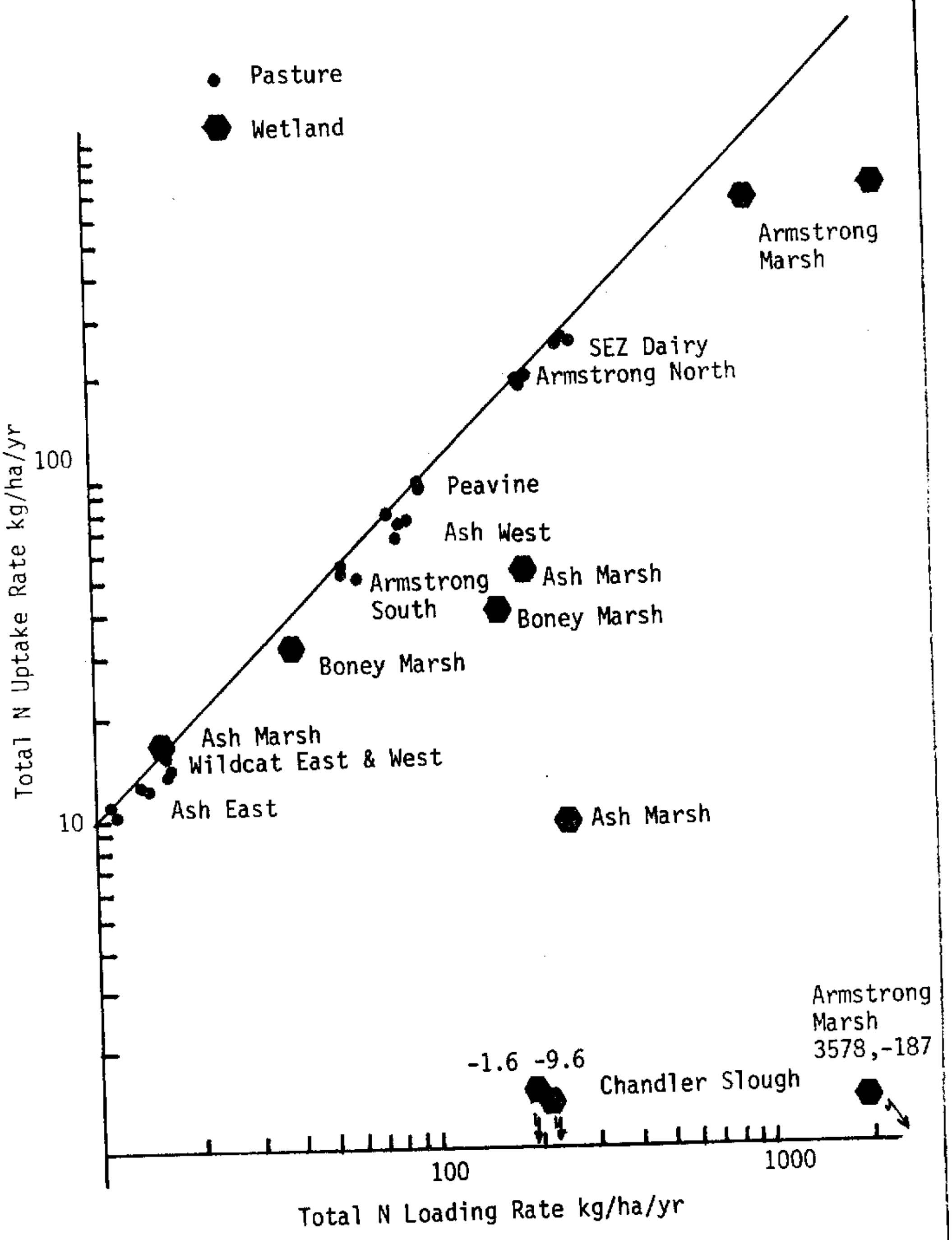


Figure I-15. Uptake Versus Loading Rates for Total Nitrogen on Pastures and Wetlands in the Kissimmee River Valley.

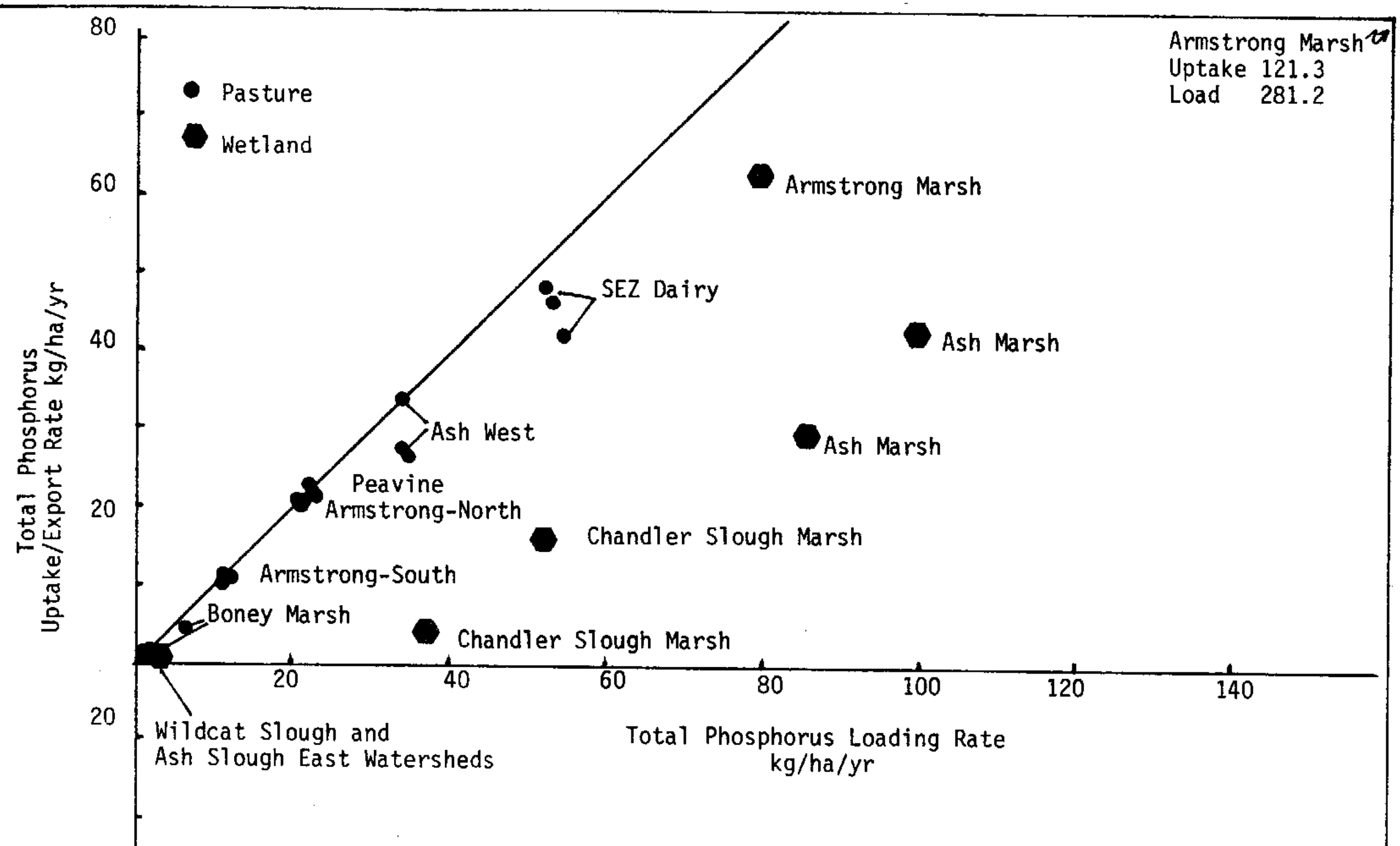


Figure I-16. Uptake versus loading rates for total phosphorus on pastures and wetlands in the Kissimmee River Valley.

Dairy watersheds are removing total N at efficiencies approaching 100 percent whereas the Ash Slough wetland and Boney Marsh uptake efficiencies are roughly 1/20 to 1/4 of those observed on the pastures. Efficiencies at Chandler Slough at the same general magnitude loading rate are negative indicating the occurrence of net export of nitrogen rather than uptake.

The same general trends seems to hold true for total P uptake efficiencies. The Ash and Armstrong Slough wetlands are loaded at rates heavier than those calculated for the upland pastures. Efficiencies of uptake in upland pastures begin to fall off at loading rates of 36 kg/ha/yr or more. Heavier loading rates of 80-90 kg/ha/yr on the Ash Slough wetland result in uptake rates generally no better than those observed in the Ash Slough-west and SEZ Dairy watersheds (about 30-45 kg/ha/yr) which are loaded at rates roughly half those of the Ash Slough wetland.

The Armstrong Slough marsh exhibited good uptake efficiency during the first year and though heavily loaded, good efficiency during the second year, but ended up with a negative efficiency (net export) during the final year of study. Efficiencies during the first two years were less than those observed in pasture lands, although direct comparison cannot be made given the much heavier loading rates in the Armstrong Slough marsh. The efficiency of P uptake in the Chandler Slough wetland was significantly lower than P uptake rates and efficiencies on pasture lands loaded at equivalent rates.

If these findings are valid, it appears that upland pasture is far more efficient at removing total N and total P loads from solution than are established wetlands. The reasons for this are probably varied. Upland pastures are subject to frequent or at least occasional harvest. Nutrient contact with the substrate has the potential to occur over a much longer period of time and much of the nutrient load may be washed into and leached through the soil in shallow or deep subsurface flow and thus not show up in surface runoff. In any event, this study suggests that well managed, improved pasture of a given surface area would be a more effective remover of nutrient loads than an established wetland of identical size if loaded at the same rates.

From the study, the following conclusions can be drawn about wetlands in the Kissimmee basin:

1. Time series and flow weighted concentrations of nitrogen and phosphorus species were consistently reduced in the Armstrong Slough marsh. The sole exception was phosphorus species concentrations during the final year of study which were enhanced.

2. Time series and flow weighted concentrations of N and P at the outfall of the Ash Slough marsh were often greater than those measured at the inflow.

3. Both wetlands consistently functioned as net retainers of nutrient loads. The majority of uptake was attributed to loss associated with flow attenuation at the outfall of the wetlands. During the final year of study, the Armstrong Slough wetland was estimated to be a net exporter of P species due to more flow being discharged from the wetland than entering via measured surface sources.

4. The dissolved inorganic species in the total N and P loads are removed much more efficiently than are the particulate forms. Dissolved inorganic N uptake efficiency consistently exceeded 50 percent. Ortho P removal efficiencies were about 40 percent at Ash Slough. At Armstrong Slough the efficiencies decreased during each year of the study. While it is conceivable that particulates in the inflows may be removed, internal cycling processes in the wetlands may be concurrently resulting in a release of like amounts of particulates, which get flushed out at the outfall. The net result is the establishment of what approaches a steady-state of import/export for these nutrient forms.

5. These wetlands are either in or approaching a steady-state with respect to nitrogen uptake.

6. These wetlands tend to be net removers of phosphorus, but the removal efficiency at Armstrong Slough exhibited an obvious decreasing trend during this study.

7. Both wetlands appear to be at best minimally efficient at removing particulate N. Efficiency of removal was good at Armstrong Slough during the first year of the study but by year three the wetland appeared to have become a net exporter.

8. Total P removal rates and removal efficiencies as compared to loading rates mirrored those magnitudes and trends calculated for ortho P species at both wetlands. During the final year of study, the Armstrong Slough wetland became a net exporter of particulate P.

9. Immediately following construction of the plug creating the Armstrong Slough wetland in May 1980, there appeared to be a reduction in magnitude and variability of nutrient concentrations at the marsh outfall. This tended to last until the fall of 1981. After that time nutrient concentrations returned to pre-plug construction levels. It is not possible to attribute this temporary reduction entirely to creation of the flow-through wetland since a record south Florida drought occurred during this same period and the wetland experienced minimal flows resulting in maximum detention times. Increases in nutrient concentrations at the outfall occurred concurrently with the ending of the drought and the associated increased flows and discharge from the marsh. Whatever the cause, be it wetland creation, reduced flows, or a combination of the two, the decrease in concentrations at the marsh outfall was relatively short-lived.

10. A "first flush" event following the 1980-81 drought occurred in August-September of 1981. During these two months, the Armstrong Slough wetland was estimated to have attenuated and reduced flow volume to downstream receiving waters by about 27 percent. At the same time, flow weighted concentrations for dissolved inorganic N, total N, ortho P, and total P were reduced by 60.0, 9.8, 22.1, and 23.5 percent respectively over those that might have been theoretically expected at the outfall. The wetland clearly did function to remove nutrients as well as reduce flows during this period.

11. Following a severe freeze in early 1982, concentrations of N and especially P increased at the Armstrong Slough marsh outfall. Since there was no concurrent increase at the major inflow monitoring station, this rise was attributed to senescence and decay of vegetation killed during the freeze. Since flows during the period were low, export of these nutrients from the wetland was minimal.

12. The Ash and Armstrong Slough wetlands appear to function in a similar manner as other Kissimmee basin wetlands (Chandler Slough, Boney Marsh) in that they are near steady-state with respect to total N, and function at about the same levels of efficiency as P sinks (less than 50 percent).

13. On a per unit uptake per unit surface area basis, these wetlands function less efficiently to take up nitrogen and phosphorus loads than do upland pastures loaded at equivalent rates.

SECTION II
INTRODUCTION

HISTORICAL PERSPECTIVE

This report is the culmination of the South Florida Water Management District's (SFWMD) participation in the Upland Detention/Retention Demonstration Project conceived by the Coordinating Council on the Restoration of the Kissimmee River Valley and Taylor Creek/Nubbin Slough Basin (KRVCC) and funded by the 1977 Florida Legislature.

The project grew out of concern for the water quality and health of Lake Okeechobee and the contribution of nutrients by its tributaries, predominantly the Kissimmee River and the Everglades Agricultural Area. These watersheds and the Taylor Creek/Nubbin Slough basin north of Lake Okeechobee were perceived to be the primary sources of the water quality threat. One of the recommendations from the 1971 Governor's Conference on Water Management in South Florida was that water quality in the lake could be improved by reflooding the then newly channelized floodplain of the Kissimmee River.

In 1973, the Florida Legislature established and funded the "Special Project to Prevent the Eutrophication of Lake Okeechobee". The project findings (Florida Division of State Planning, 1976) were that Lake Okeechobee was already in a eutrophic condition due to nutrient loads entering the lake primarily from the above mentioned watershed. Other project findings were that water quality could be protected by retaining rainfall on the uplands by using storage in wetlands and the shallow aquifer. Other recommended actions were to improve farming and ranching techniques with water quality and conservation in mind and to flood publicly owned wetlands in the Kissimmee Valley and Upper Chain of Lakes.

In 1976, the Florida Legislature created the Coordinating Council and directed that "in recognition of the findings of the Special Project" it should develop measures to restore the water quality of the Kissimmee River Valley and Taylor Creek/Nubbin Slough basin. The KRVCC requested and received funds from the 1977 Florida Legislature for the Upland Detention/Retention Demonstration Project. The project was to test the use of non-structural and minimum structural alternatives for water management. The emphasis focused on the use of existing or recreated wetlands as detention/retention sites for treating nonpoint source pollution from agricultural runoff (McCaffrey, et al 1977).

The SFWMD participated in the project as the entity contracted to perform the tasks of construction, hydrological monitoring, and water quality monitoring and evaluation. A number of potential agricultural study sites in the Kissimmee Basin were investigated and five were eventually chosen. These sites were all basically used for cattle grazing, but varied in intensity of management activities and density of animals from native range to large dairy staging and holding areas. The SFWMD investigation effort was designed to address two basic questions:

1. How do agricultural land use intensities and practices typical in the basin impact quality of nonpoint source stormwater runoff, and

2. Would existing and recreated wetlands used as detention/retention facilities be effective in reducing nutrient loads from nonpoint source runoff originating from agricultural lands.

This report is the documentation of these studies. The results provide good insights into the manner in which agricultural practices impact runoff and the effectiveness of wetlands in the basin to reduce nutrient loads present in the runoff from these agricultural lands.

REPORT ORGANIZATION

The remainder of this introductory section will provide a brief description of the general project area, the climatic conditions that occurred during the study period, and a description of each of the five project study sites. The entire report is comprised of six major sections. These are:

Section I: Executive Summary and Conclusions - - This section briefly summarizes the study and lists the major results and conclusions.

Section II: Introduction - - This section

Section III: Field and Laboratory Methods - - Data collection and laboratory analytical methods are described.

Section IV: Rainfall Analysis - - This is a description of the rationale and methodology of how rainfall quantity and quality were evaluated and used to estimate impacts of rainfall on nonpoint source quality.

Section V: Surface Water Quality Studies - - This is a description of the basic water quality studies conducted on the five study sites and answers the question of agricultural land use impacts on nonpoint source runoff quality.

Section VI: Utilization of Wetlands as Detention/Retention for Enhancement of Quality of Nonpoint Source Agricultural Runoff - - This last section evaluates the effectiveness of wetlands as BMPs for mitigating nutrient loads in nonpoint source runoff.

ACKNOWLEDGMENTS

This project was conducted and completed as a result of efforts by staff members of virtually every Department and Division of the SFWMD from the Executive Director, who sits as a member of the KRVCC, on through the cadre of engineers, scientists, technicians, surveyors, field workers, clerks, secretaries, and other administrative personnel who all played some role in the ultimate success. Special recognition and gratitude are extended to the participating landowners who, through their consent and cooperation, were the major factor in the success of the endeavor. These were:

Lykes Brothers Inc. - Brighton, Florida - Mr. Al Waggoner
Latt Maxcy, Corp. - Frostproof, Florida - Mr. Pat Wilson
Mr. J.C. Bass - Basinger, Florida
Mr. Robert Goolsby - Okeechobee, Florida

GENERAL AREA

The Upland Demonstration Project was conducted on five sites in the Kissimmee River watershed of south-central Florida. The sites, situated over three counties (Osceola, Highlands, and Okeechobee), were chosen to represent a spectrum of agricultural land uses typical of the practices that characterize the beef, dairy, and citrus industries in the project area. The five study sites are depicted in Figure II-1. Four of the five sites lie in a physiographic feature known as the Osceola Plain; the fifth, in Highlands County, is located on a similar feature of lower elevation called the Okeechobee Plain. The Osceola Plain is a broad flat scarp with a gradual downward slope from north to south with local relief rarely exceeding 1.5 m. The Okeechobee Plain is flat and featureless, covering a large portion of the area between Lakes Istokpoga and Okeechobee. It, too, slopes downward in a southerly direction. The climate of the area is subtropical. Average annual rainfall is 127-139 cm with the heaviest occurring between June and October (Lane et al, 1980).

With the exception of the last year at Armstrong Slough, the three year study period from October 1, 1979 to September 30, 1984 had annual rainfall totals at all sites less than historical normal amounts (mean annual rainfalls). During the period from Fall of 1980 through early Spring 1982, south Florida experienced one of the worst droughts in its recent history. Consequently, runoff amounts and water quality from these watersheds reflect the impacts of this extreme event. The remaining months of 1982 reflected near or above normal historical rainfall amounts. No period of above normal annual rainfall occurred during the study period.

Soils in the project area in Okeechobee County are typically sandy, with an organic hardpan at a depth that varies from 10 to 48 inches (McCollum and Pendleton, 1971). Predominant soil associations are Myakka-Bassinger and Immokalee-Pompano. These are typical of the broad flatwoods and open prairies of the area. These soils are typically strongly acid and very porous, but poorly drained. Typical vegetation found on these soils are saw-palmetto, slash pine, gallberry, fetterbush, runner oak, and various grasses.

Soils on project sites in Osceola County are predominantly Smyrna-Myakka-Immokalee and Eau Gallie-Smyrna-Malabar Associations (Readle, 1979). These sandy soils have general drainage characteristics similar to those described for predominant soils at Okeechobee County study sites and support similar types of vegetation.

General land use at the study sites and throughout the project area is primarily beef and dairy cattle grazing. Other land uses that are interspersed throughout are citrus and some row crops.

SPECIFIC PROJECT STUDY SITES

<u>WILDCAT SLOUGH</u> - The Wildcat Slough study watershed (Figure II-2) is located on Lykes Bros., Inc. ranch property in Highlands County north of Brighton at the intersection of S.R. 70 and canal C-41A. The drainage basin area covers some 15,680 acres (6,348 ha) and is located in Township 37 S, Range 32 E.

Rainfall runoff from this site is conveyed through two major channels and drains into C-41A through five 72-inch culverts. Three sampling stations were located on this site. One station was established in the main channel roughly three miles upstream of C-41A (Section 10). This station (Station 3) monitors runoff from a 6,400 acre (2,591 ha) basin consisting of predominantly native pasture with some slightly improved rangeland. This area is used for low density

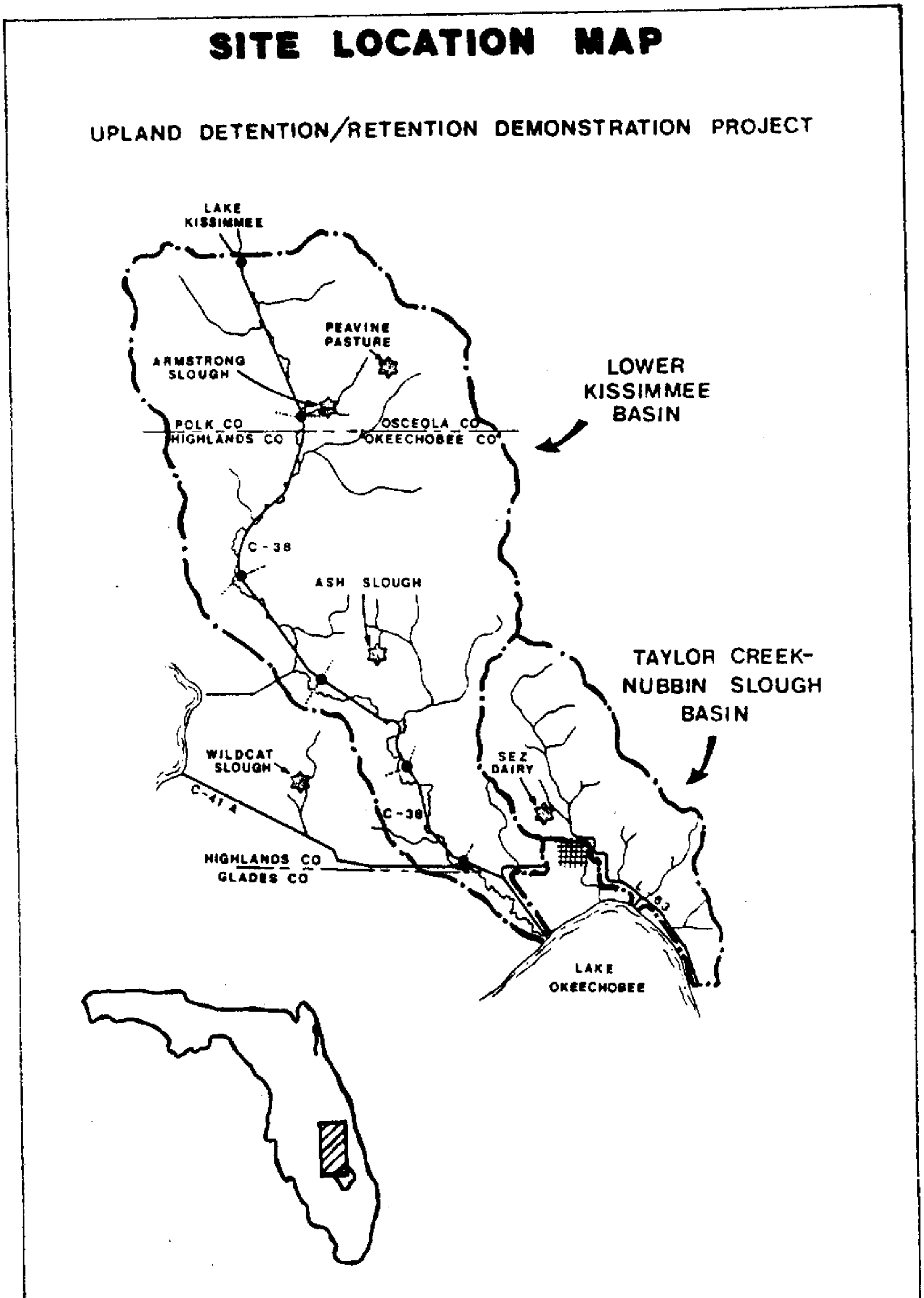


Figure II-1. Upland Demonstration Project Study Area.

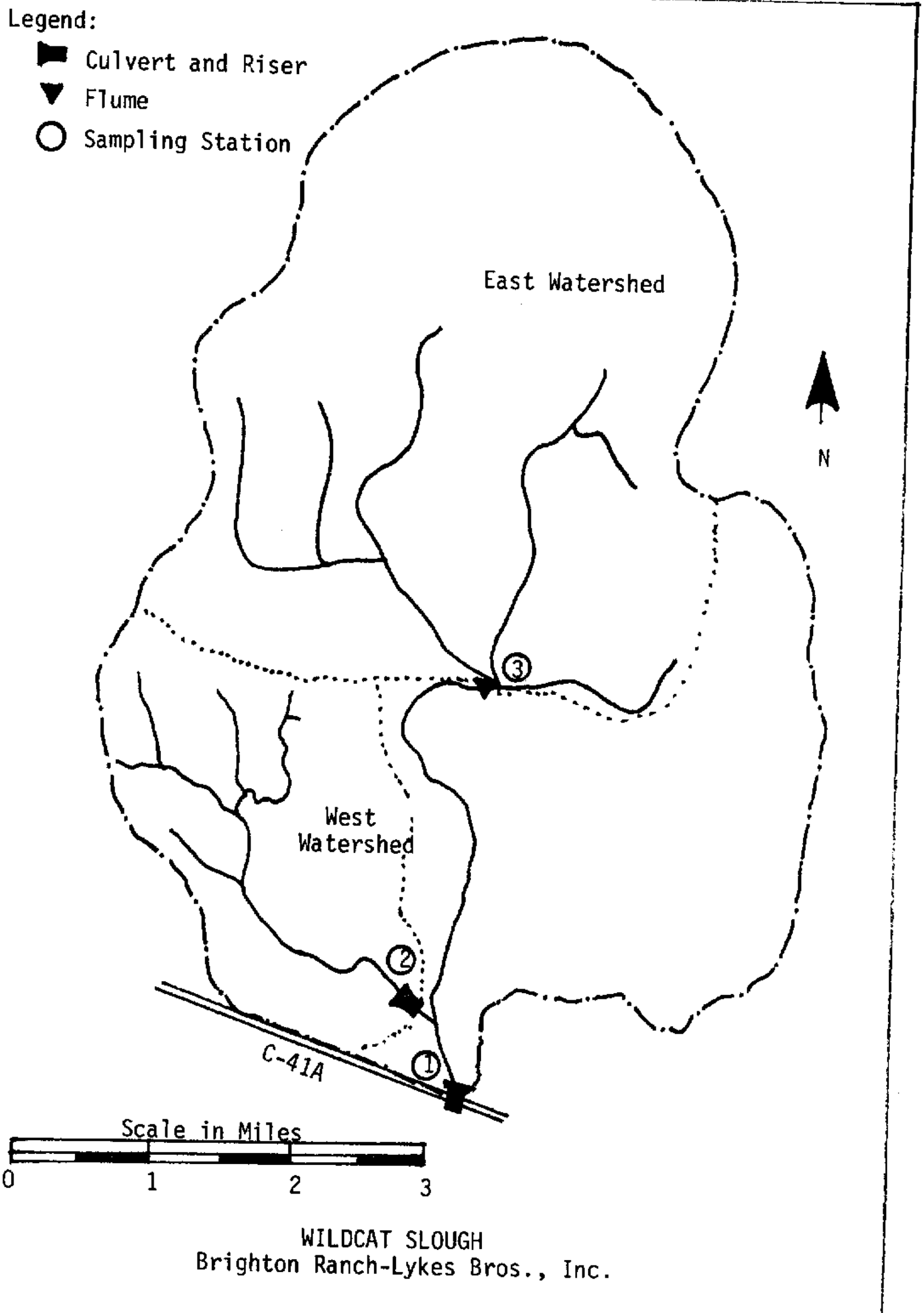


Figure II-2. Wildcat Slough-Conveyance Channels and Sampling Stations.

(.05 cows/acre) cattle grazing. A concrete criticial depth flume was installed at this location to enable collection of accurate flow data. Water quality samples were collected immediately upstream of this flume. A second sampling location (Station 2) was located in a smaller but main tributary channel that drains a 4,270 acre (1,729 ha) area of native rangeland, hardwood hammock, and marsh at the western portion of the site (Section 22). One 48-inch culvert with risers and flashboards was located in the channel and was used to measure flows. Water quality samples were collected immediately upstream of the culvert. Station 1 was located just upstream of the site outfall culverts at C-41A (Section 22). The 5,200-acre (2,105 ha) watershed area between Station 1 and Stations 2 and 3 is predominantly native to slightly improved rangeland and supports a low density (.05 cows/acre) cattle grazing operation.

<u>**ASH SLOUGH**</u> - The Ash Slough study site (Figure II-3) is located in Okeechobee County (Township 35 S, Range 33 E, Section 17) about five miles north of Basinger on the J.C. Bass Ranch. The study site consists of two distinct watersheds (pasture blocks) that drain into a common lower marsh area. The marsh, intermittently dry and inundated, covers about 20 acres (8.1 ha) and discharge from it reaches Ash Slough which is situated some distance downstream from the culvert flow and stage control structures at the outfall. The two watersheds are both situated on predominantly Myakka-type soils. The major portion of the study site consists of a 170-acre (68.8 ha) improved pasture watershed extensively ditched for drainage purposes. The land west of the marsh was formerly cultivated in tomatoes and was converted several years ago to improved pasture. Grazing density is fairly high at .33 cattle/acre. Predominant vegetation cover is <u>Hemarthria altissima</u> grass. A concrete criticial-depth flume was constructed in the single major ditch that conveys water collected in the ditched watershed to the marsh. A water quality monitoring station (Station 2) was established just upstream of this flume.

The watershed on the east side of the marsh is unditched and significantly smaller {approximately 50 acres (20.2 ha)}. This pasture, predominantly planted in Pangola grass (<u>Digitaria</u> spp.), is also used for cattle grazing at roughly the same animal density (.33 cattle/acre) as the western pasture. A shallow ditch was dug parallel to the marsh to intercept the sheet flow of water coming off this pasture as it drained. This water was then diverted via a small ditch perpendicular to the interceptor ditch into the marsh. A small concrete critical-depth flume was constructed in this conveyance ditch. A water quality sampling station (Station 4) was located just upstream of the flume.

A water quality monitoring station (Station 1) was established just upstream of the two 18-inch culverts at the outfall of the Ash Slough marsh. These culverts were fitted with risers so the water level in the marsh could be manipulated by the use of removable stoplogs as the need arose.

A water quality monitoring station (Station 3) was established in a ditch connecting the drainage systems of two major pasture blocks at the beginning of the study. Alterations in the drainage system by the landowner early in the study resulted in loss of integrity of hydrological measurement; thus the ditch was plugged and the sampling station abandoned.

<u>**ARMSTRONG SLOUGH**</u> - The Armstrong Slough site (Figure II-4) was located on Latt Maxcy Corporation property in Osceola County about six miles south of State Road 60 and east of the Kissimmee River just upstream of the S-65A control structure (Township 32 S, Range 32 E, Section 27). Three sampling stations were established at this site where both water quality and quantity were monitored on a routine basis. One sampling station was located in each of the two tributary channels contributing flow into the Armstrong Slough marsh. The northernmost channel drains a watershed of approximately 7,500 acres (3,036 ha) of mixed use agricultural land. The major land uses are light to moderate density livestock grazing (.20 cows/acre) and citrus groves. Citrus comprises roughly 7.5 percent of the total watershed area. Soils are predominantly Smyrna fine sand and Myakka fine sand. The monitoring station (Station 2) was located in a section of well defined open channel roughly one mile upstream of the site outfall culverts under the access road to the S-65A lock structure on the Kissimmee River. Typical pasture vegetation is predominantly Pangola with some interspersed Bahia (<u>Paspalum notatum</u>) and torpedo (<u>Panicum repens.</u>) grass.

The south tributary drains an area of approximately 2,500 acres (1,012 ha) of improved pasture and native range. The land is used predominantly for low density livestock grazing. Soils in the southern watershed are mostly Smyrna fine sand with lesser but approximately equal amounts of Eau Gallie and Malabar fine sands. The monitoring location (Station 3) was established immediately upstream of the concrete flow monitoring flume which was constructed by the SFWMD to enable accurate flow measurements to be made at this location.

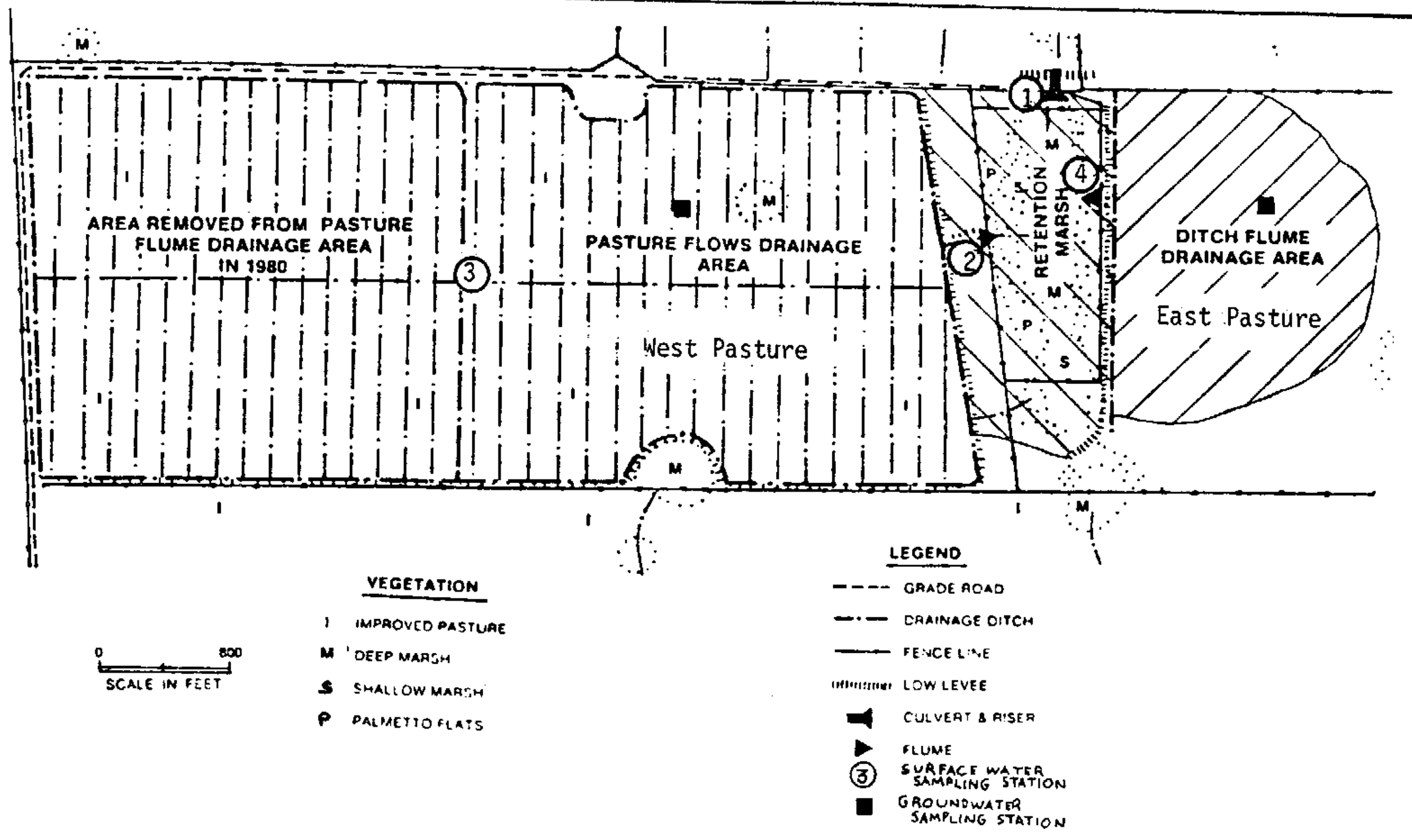


Figure II-3. Ash Slough Detention/Retention Marsh and Tributary Watersheds.

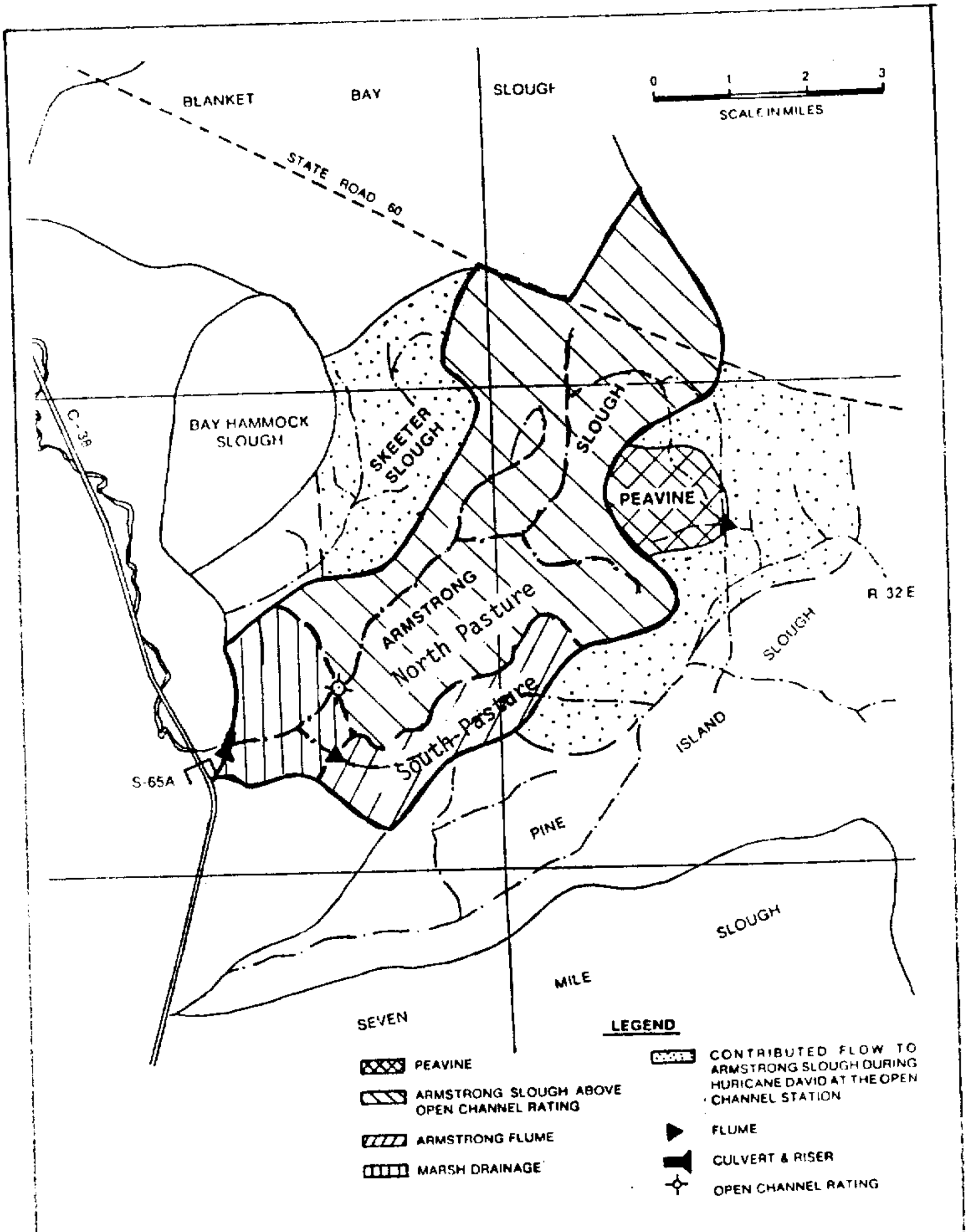


Figure II-4. Armstrong Slough and Adjacent Watersheds.

Prior to May of 1980, the southern tributary channel drained through an approximately 80-acre marsh before finally draining into the northern conveyance channel just upstream of the site outfall culverts. The northern channel was well defined and flow was contained within the banks at all times except during the rainfall/discharge events acompanying Hurricane David. During May 1980, SFWMD construction crews plugged the northern channel at a point about one quarter mile upstream of the outfall culverts in an attempt to create additional marsh by forcing water out of the channel and across the adjacent low lying areas (Figure II-5). The present area of ungauged inflow to the marsh area is some 453 acres (183.4 ha). The marsh itself now occupies an average surface area of some 30 acres (12.1 ha). Soil types in and around the marsh are predominantly Immokalee fine sand with lesser amounts of Placid fine sand and Samsula muck.

The site outfall monitoring station (Station 1) is located upstream of six 72-inch culverts under the access road to the S-65A structure. These culverts were fitted with risers and flashboards so that water levels could be manipulated on a predetermined seasonal basis or as discharge events dictated. Water stages in the marsh rarely ranged outside of 48-50 feet mean sea level during the study.

PEAVINE PASTURE - The Peavine Pasture study site (Figure II-6) was located on Latt Maxcy Corporation property in Osceola County about two miles south of State Road 60 on the west side of Old Peavine Road (Township 32 S, Range 33 E, Section 9). The watershed consists of approximately 600 acres (243 ha) of improved pasture supporting light to moderate (.20 cows/acre) grazing practices. Soil types are predominantly Eau Gallie fine sand with lesser amounts of Malabar fine sand and Myakka fine sand. Vegetative cover is primarily carpet (*Axonopus* spp.) and Pangola (*Digitaria* spp.) grasses interspersed with clumps of palmetto (*Serenoa repens*).

A concrete critical-depth flume was installed at the site outfall to accurately measure discharge from surface runoff at this location. A water quality sampling station (Station 1) was established immediately upstream of the sampling site. The northern channel is plugged at the watershed boundary. The southern channel originates on site at a location in the central portion of the watershed. Two additional water quality sampling locations were established in this channel.

SEZ DAIRY - The SEZ Dairy site (Figure II-7) is a 718-acre (291 ha) dairy located in Okeechobee County about three miles northwest of the city of Okeechobee (Township 37 S, Range 35 E, Sections 5, 6, 7). The western portion of the site supports a high density cattle holding and grazing dairy operation of some 500 head of milking cows plus an additional 200-500 head heifer and calfing operation. The central and eastern portions of the dairy are used for grazing and haying operations. Wastewater from the milking barn complex drains into a Soil Conservation Service-designed waste stabilization lagoon system. This system consists of a 1.5 acre (.61 ha) surface area first stage settling lagoon and a 3.7 acre (1.5 ha) surface area second stage holding lagoon. Conceptually, effluent from the second lagoon is released to a ditched seepage irrigation system, thus putting discharged nutrients onto the land. In reality, this system suffers maintenance and management shortcomings (Goldstein and Ulevich, July 1980) such that when discharge from the lagoon system occurs, it flows directly into the perimeter ditch on the north edge of the property and is subsequently discharged directly into Wolf Creek, a tributary in the Taylor Creek drainage basin.

Soils at the site are predominantly Immokalee interspersed with some Myakka and Bassinger-Pompano fine sands. Predominant vegetation is Pangola grass.

The dairy is surrounded by a perimeter drainage ditch that discharges at only one site, the above described Wolf Creek outfall. Station 1 was located immediately upstream of the 24-inch culvert and riser system that is used for flow control at this point. Five additional water quality sampling locations were located at points throughout the dairy. Station 2 was established midway down the concrete trough that conveys barnwash to the first lagoon. Station 3 was located in the first lagoon at a point immediately in front of the pump intake where excess water from the first lagoon is moved into the second lagoon. Station 4 is located in the second lagoon, just in front of the stage control riser and culvert at the discharge point of the second lagoon. Stations 5 and 6 were located midway down the north and south perimeter ditches, respectively. Flow volumes were monitored at the site outfall (Station 1) and at discharges from both lagoons (Stations 3 and 4).

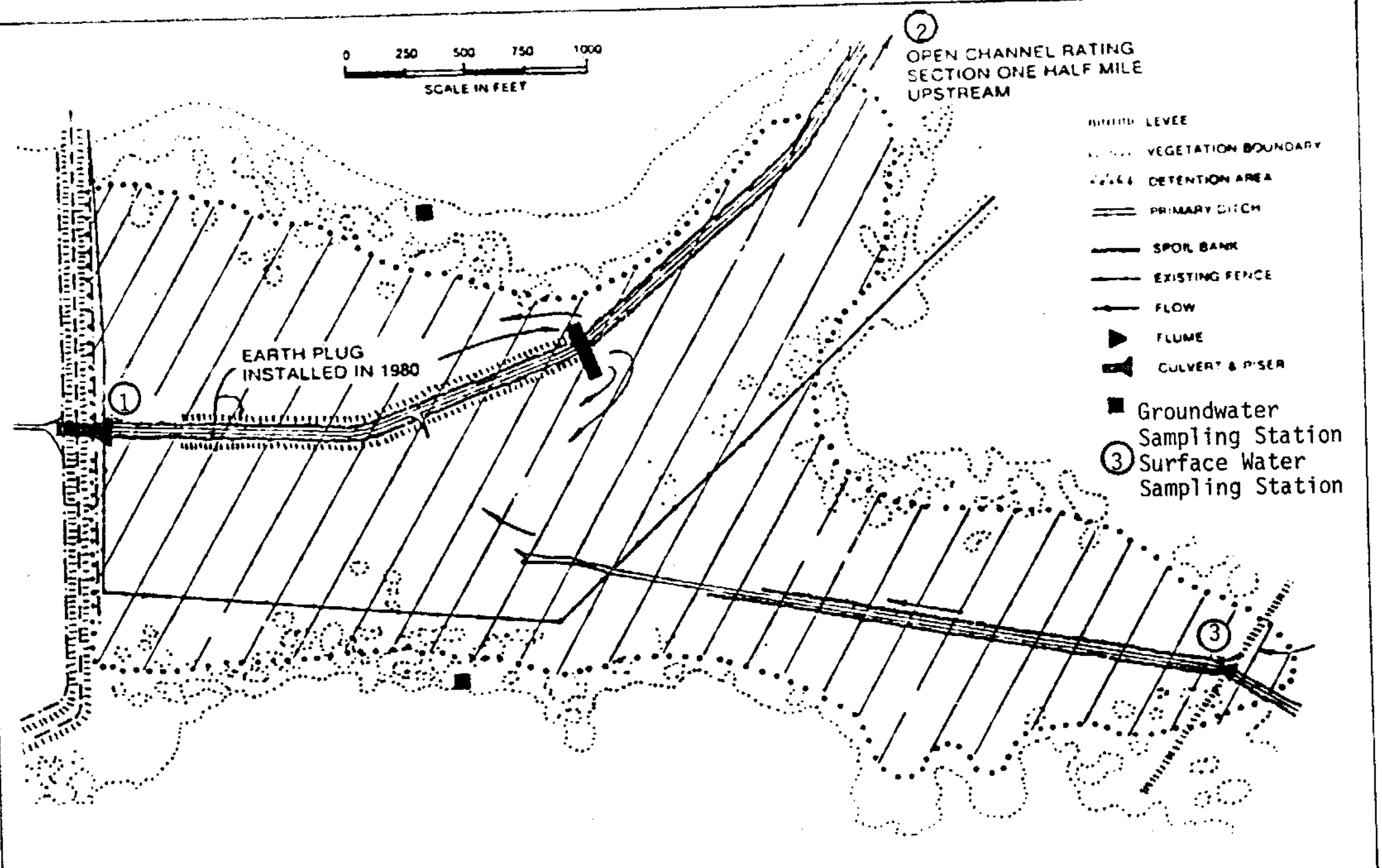


Figure II-5. Armstrong Slough Detention/Retention Wetland.

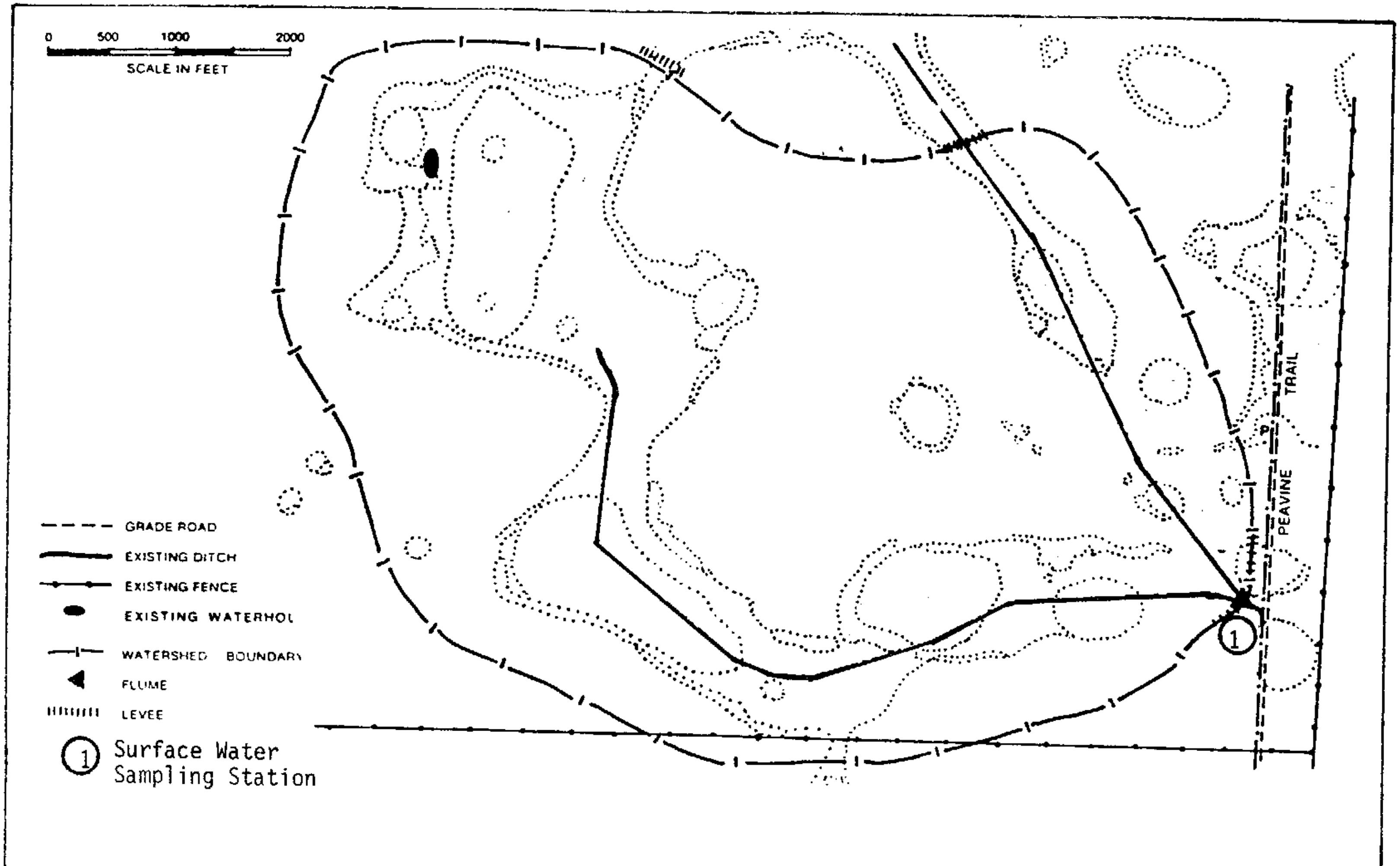


Figure II-6. Peavine Pasture Watershed.

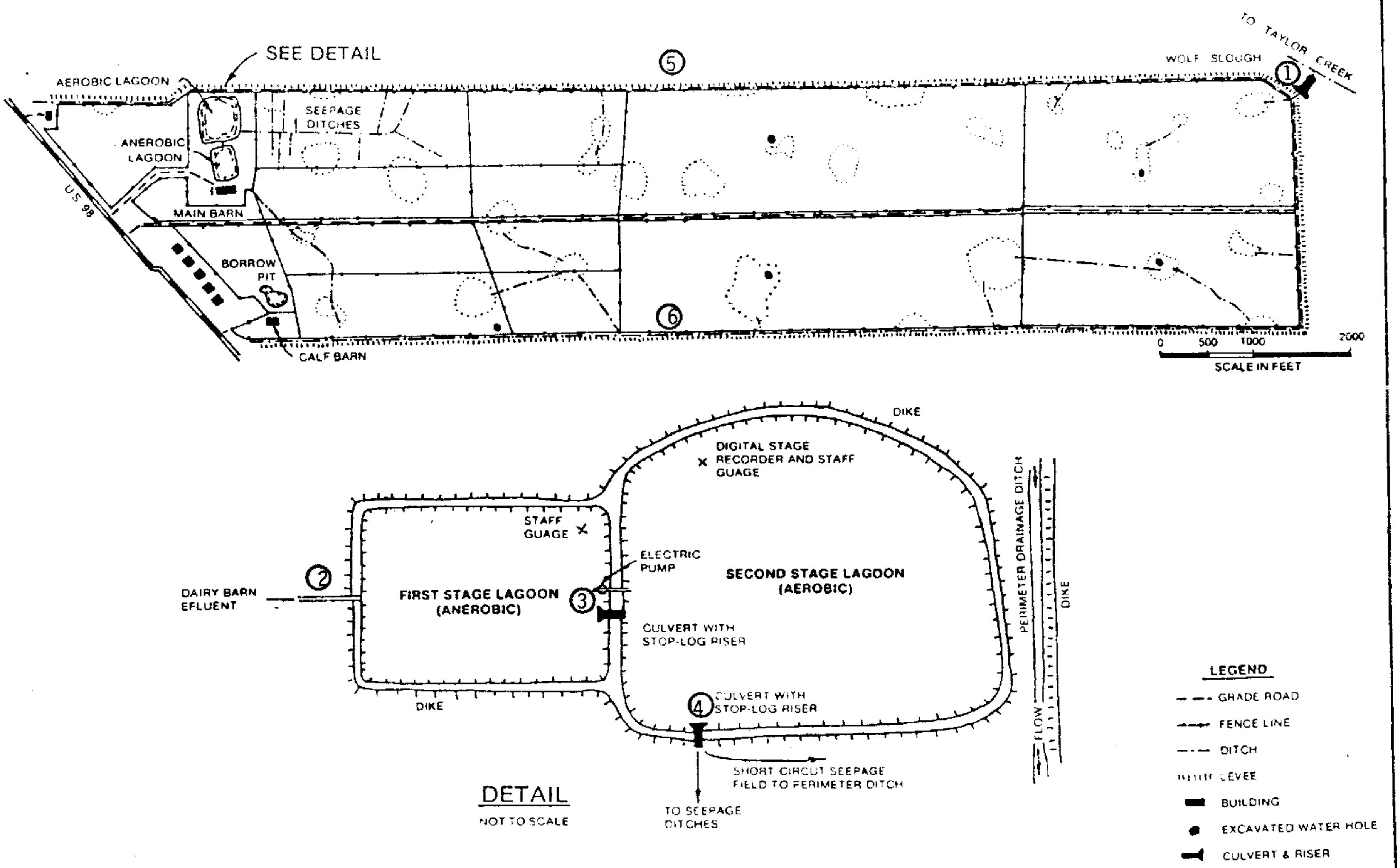


Figure II-7. SEZ Dairy Watershed and Lagoon.

SECTION III
FIELD AND LABORATORY METHODS

INTRODUCTION

In order to calculate mass transport and nutrient flux occurring at each project site, it was necessary to collect data on both surface water and rainfall quantity and quality. Stations were established at appropriate locations in each of the major conveyance channels draining the study watersheds and at each of the inflow and outlet channels at the two detention/ retention wetland study sites.

From 1978 through 1981, water quality samples, once collected, were analyzed at the SFWMD laboratory in Okeechobee. This laboratory was considered a satellite facility to the District's water chemistry laboratory at West Palm Beach. The express purpose of the Okeechobee laboratory was to provide analytical services in support of the Upland Demonstration Project. At the end of 1981, laboratory services at Okeechobee were discontinued and all subsequent sample analyses were conducted at the District's main laboratory at West Palm Beach.

The following discussion will review site preparation activities necessary to establish hydrological integrity and measure flow volumes. Hydrological as well as surface water and rainfall quality sampling methods will be described and discussed. The section will conclude with a brief description of laboratory analytical methods. A detailed description of labortory procedures is provided in Goldstein et al (1980).

Data reduction and analytical rationale will not be addressed in this section, but will be discussed in each of the following sections where its inclusion will be more appropriate.

SITE PREPARATION

Some site preparation and alterations were necessary at four of the five Upland D/R Project study locations. The fifth, SEZ Dairy, was already a discrete hydrological unit, being surrounded on three of four sides by a deep perimeter ditch that contained all runoff, and on the fourth by the crown of U.S. Highway 98. Activities to catch runoff and prevent inter-watershed gain or loss were confined mainly to construction of interceptor ditches, sand plugs in channels, and tieback and training levees. In one instance, new culverts were installed when the old ones were found to be less than adequate. The activities required to satisfactorily alter each site were as follows:

WILDCAT SLOUGH - Relatively minor modifications to the existing drainage system were required at this site. The primary modification was the installation of a tieback levee across a poorly defined channel and an associated flow monitoring structure (concrete flume) at Station 3.

ASH SLOUGH - This site required some rather extensive modifications to create and insure hydrological integrity of the detention/retention marsh area.

The smaller (about 50 acre or 20.2 ha) watershed was a fairly discrete unit; however, due to the flatness of the terrain, runoff was virtually of a sheetflow nature. To be able to perform flow measurements, runoff had to be collected and funneled through a conveyance channel of known cross-sectional area. To do this, an interceptor ditch running north-south along the periphery of the marsh was dug to collect the sheetflow. A ditch was then dug perpendicular to, and continuous with, the interceptor ditch. This additional channel served to convey the collected sheetflow into the marsh and quantity measurements were facilitated by construction of a concrete flume structure in the channel.

The larger west watershed (156 acres or 63 ha) was already extensively ditched for drainage. Creating hydrological integrity at this site was accomplished by merely dressing the existing ditch and levee on the western periphery of the marsh and installing a sand plug in the single common conveyance channel between the subject watershed and a similar block of ditched pasture immediately adjacent to the west. A single conveyance ditch leading into the marsh was already in existence. A concrete flume structure was installed in the channel to assist in measuring flows.

A certain amount of runoff detention in the marsh was insured by construction of a levee at the discharge side of the wetland and installation of 24-inch culverts with attached risers. Use of flashboards in the risers allowed some manipulation of the water levels in the marsh if such was deemed desirable by the landowner.

Cattle activity in the area frequently created breaches in the levees at both the interceptor ditch on the east and the peripheral drainage ditch on the west. Flow through these breaches during periods of excessive runoff compromised the hydrological integrity of the marsh and reduced the accuracy of flow measurements from the contributing watershed during these extreme periods. These ditches and levees were redressed during the course of the study, but within a few months, cattle traffic would invariably create new breaches. Initial construction at the site was completed in the Spring of 1979.

ARMSTRONG SLOUGH - Contributing watersheds at the Armstrong Slough study site were judged to be of sufficient hydrological integrity such that no modifications in the watersheds were required. A tie-back levee and flow monitoring structure across the channel of the south tributary was constructed up-stream of the recreated wetland. A series of culverts which were in poor condition were replaced with six 72-inch culverts with risers at the downstream portion of the marsh to provide both water level control and a means of measuring flow leaving the wetland. In the Spring of 1980, an earthen plug was designed and subsequently constructed in the Armstrong Slough main channel about 500 yards (470 meters) upstream of the large culverts. This plug was an elongated structure almost 1,200 feet (365 meters) long encompassing a central equalization pond. The purpose of the plug and associated diversion ditches was to detour water from the main channel and force it out over the low-lying areas to the north and south, thereby creating a continuous flow through the marsh. Reduction in flow velocity and the resulting increased exposure in wetlands facilitated the settling of suspended solids and increased the time and exposed substrate surface area required to enhance nutrient conversion and uptake. Construction at this site was completed in early June 1980.

PEAVINE PASTURE - Construction rquirements at the Peavine site were minimal. A small concrete flume and associated short tieback levee were installed at the outflow of the site. Sand plugs were installed in two channels on the peripheries of the watershed to create a closed discrete hydrological unit. This work was completed in March 1979.

SEZ DAIRY - As previously discussed, no modific-ations to this site were required.

HYDROLOGY

Flow data at each site were obtained indirectly through the use of flow control structures, available stage data, and application of the appropriate flow equation for the type of outflow structure (flume or culvert) in use at each gaging location. Instantaneous flow rates were mathematically calculated by the use of Fisher and Porter digital punch stage recorders set at 30-minute intervals. This scheme resulted in 48 daily stage recordings and a like number of instantanteous flow volume data points at each station where stage recorders were located. These rates were multipled by the corresponding time interval and summed to yield daily flow volumes:

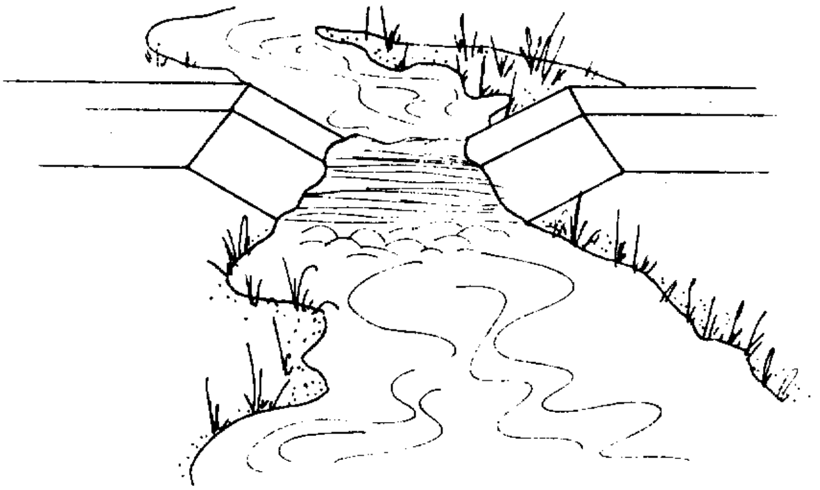
$$\text{Daily flow volume } (Qi_{1\text{-}48}) = (Qi_1 + Qi_2 + \ldots + Qi_{48})$$

where Qi = flow volume for 30-minute interval

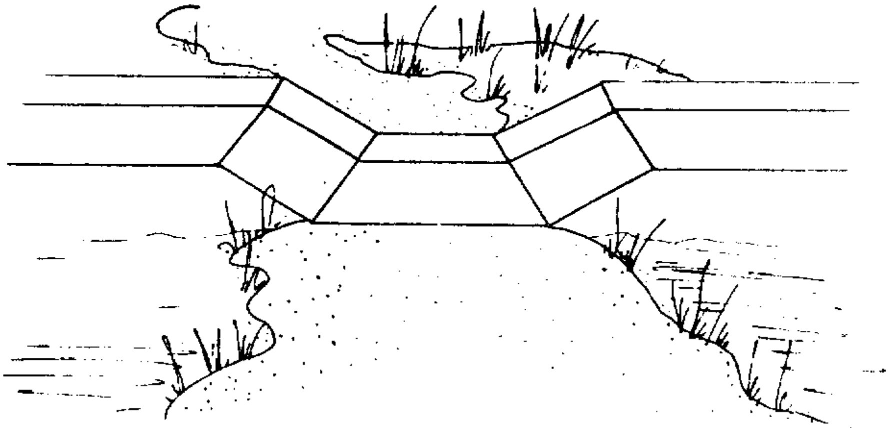
FLOW CONTROL/MEASUREMENT STRUCTURES - Two types of structures were used to measure, and in some cases, control inflow and outflow at the project study sites. These structures were critical flow flumes and culverts with risers and stop-logs. In addition, at one site, an open channel rating was established and maintained. In conjunction with available stage information provided by pairs of on-site stage recorders, stage-discharge relationships were established that were used to calculate flows.

Flumes - Critical flow flumes were designed specifically for the computation of flow rates from stage data. The term "critical depth" refers to the depth at which the flow undergoes a transition between sub and super critical flow. Where critical flow is achieved, a series of well established energy relationships is used in conjunction with approach channel characteristics to compute flow rates. The flumes for this project were designed so that critical flow was established in a region of parallel flow within the throat of the flume (Figure III-1). A computer program adopted from Replogle (1975) was used for performing the computations that converted stage data to flow rates.

Although flumes have proven to be very accurate for flow measurements, care was taken to insure that they were sized correctly for the anticipated range of flow to be measured. This was done to minimize inaccuracies in flow measurements that result from very low stages at oversized flumes. The flumes for this project were sized so that the influence of these low stages on the reliability of monthly and yearly flow volume was negligible. At high stages, the downstream water level was checked against that upstream to insure that there was enough head drop for the transition to critical flow to occur in the flume throat. When the stages were within the design range of the flume, the results of the flow calculations were accurate within $\pm$ 5.0 percent. The District's computer program for calculating flume discharge was



CRITICAL DEPTH FLUME WITH FLOW



CRITICAL DEPTH FLUME WITHOUT FLOW

Figure III-1. Schematic of Critical Depth Flume for Flow Measurements.

designed to check every data point for conformance with the design limits of each site. Low flow, insufficient head drop, or reverse flow conditions were all flagged separately. Flagged values were investigated individually to determine the best estimate of flow for each occurrence.

Culverts - The culverts used for outflow control on this project were equipped with risers and stoplogs at the upstream end (Figure III-2). These structures were designed primarily to maintain a specified water level upstream. Reasonable estimates of the flow rates through the culverts could be made under most circumstances, assuming that the inlet was well maintained and an accurate log was kept of the stoplog position at all times.

For the purpose of flow computation, the structures were treated as horizontal, sharp crested weirs with end contractions. Methodology of flow calculation was adapted from King and Brater (1963). The basic equation is:

$$Q = C_e L_e H_e^{3/2}$$

where:

Q is discharge through the culverts; C_e is the discharge coefficient. This is a function of inlet width, channel width, channel depth at the inlet head;

L_e is the equivalent length. This term is based on the size of the riser opening adjusted for the ratio of the structure width to the channel width. L is modified if there are any I-beam supports in the center of the riser as is the case with the larger culverts.

H_e is equivalent head determined by subtracting the elevation of the stoplogs from the upstream stage. A factor of .003 is added to incorporate the effects of surface tension.

While flow calculations at culverts are reasonable and reliable, the nature of the culvert structure prohibits accuracy on a level equivalent to that achieved by use of the critical depth flumes. When downstream water levels were above the stoplogs, the final flow value was adjusted by a factor applied to similar conditions over a sharp crested weir (King and Brater, 1963). Some factors affecting accuracy were floating debris, weeds, stoplog condition, reverse flows, culvert control and/or inaccurate stoplog records. Under ideal conditions, this method was expected to be accurate to within ± 15 percent.

OPEN CHANNEL RATING Direct calibration of open channel flows is difficult and time consuming, particularly in sand bed channels which are subject to continuous scours and fill. It was recognized that changing characteristics of the channel would have a dramatic influence on the relationship between stage and discharge in channels of this type. Further complications were possible when severe backwater effects caused the stage to change independently of the discharge. This situation is common where there is a movable control downstream of the measuring site. Manipulation of the control to change water levels upstream of the control may influence water levels at the measuring site independent of the flow passing the site.

The open channel flow rating used in this study was located on the main channel of Armstrong Slough upstream of the detention area. Biweekly flow measurements were made manually using conventional open channel flow measurement techniques. An equation of the form DISCHARGE = A (Stage - B)^C is used to relate discharge to stage, where A, B, and C are constants selected to fit the equation to the weekly flow measurements. It was necessary to use different coefficients for the low flow range and the high flow range. These coefficients were reviewed periodically to determine rating shifts.

A screening of data available between March 1979 and April 1980 indicated that backwater effects were not significant during this period. Installation of an earthen plug in the channel downstream of the monitoring station in May of 1980 did result in backwater effects at the station. Overall accuracy of flow measurements there subsequent to that date are considered to be accurate to within ± 35 to 40 percent.

DATA COLLECTION AND VERIFICATION - Digital punch tapes were collected from all project stage recorders on a routine monthly basis. The tapes were processed by personnel from the District's Data Management and Water Resources Divisions, who also provided interpretation and verification services.

Data verification techniques included (1) the automatic flagging routines previously discussed, (2) input routines which insured that data stored in the computer were properly loaded and labeled with respect to date, time, and station indentification, (3) checks to insure that only values within a legitimate range were entered, and (4) a comparison of both stage and discharge hydrographs at similar stations done by plotting several stations on one computer plot. This allowed a rough check on auxiliary data such as operation logs on culvert structures and provided a good check for consistent datum elevations.

Flow data was used in conjunction with water quality data to calculate quantities of materials transport occurring at each monitoring station.

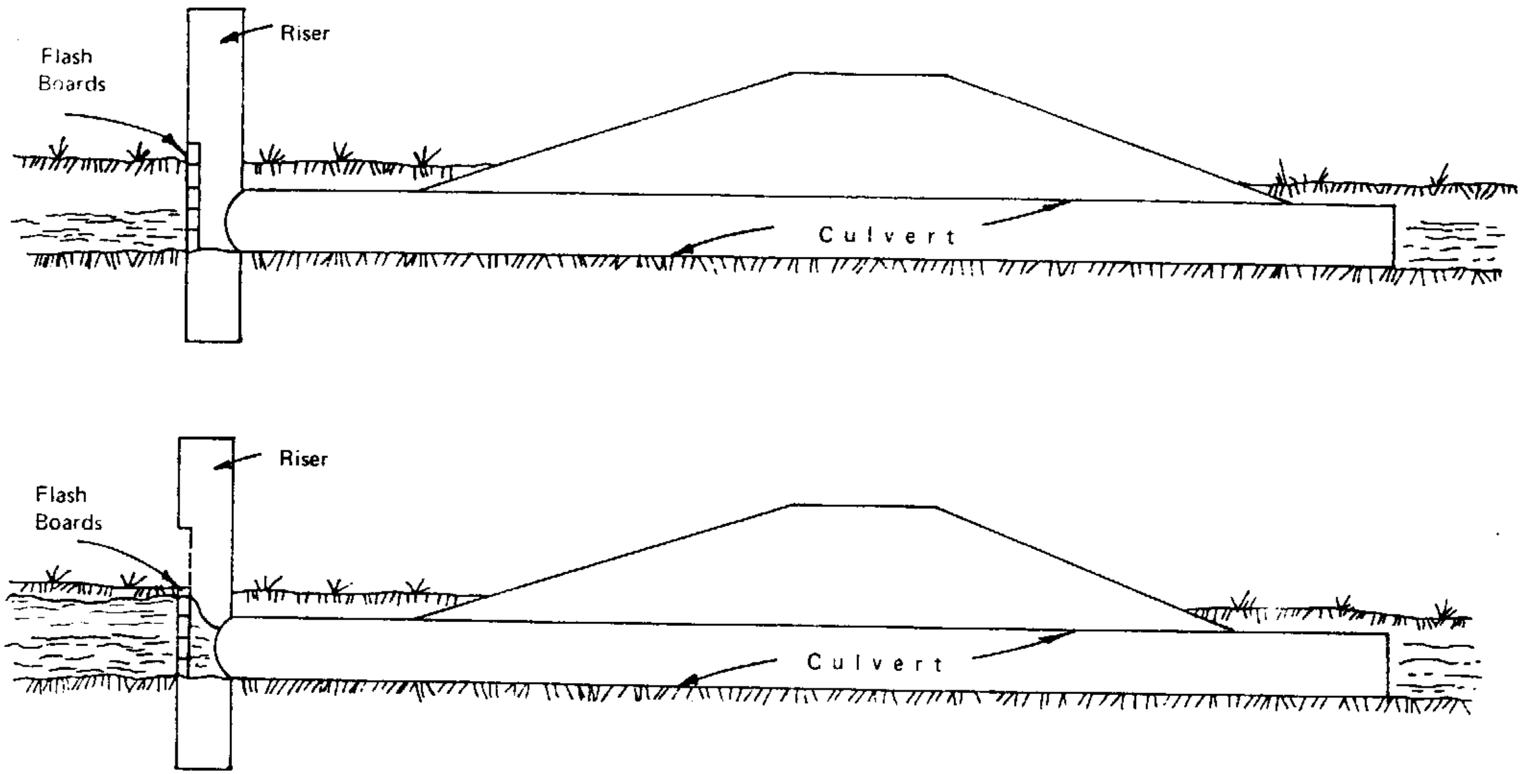


Figure III-2. Horizontal Schematic of Culvert with Riser Flow Control Structure.

WATER QUALITY

Surface water samples were collected for water quality analysis based on either a routine periodic regime established at all study watersheds, or on a storm event basis at selected locations. The latter was established primarily at the Ash Slough site to evaluate the nutrient flux at the detention/retention wetland there. Sampling regimes and methodology are described as follows.

ROUTINE SAMPLING - As a rule, routine periodic water quality samples were collected at all stations at two-week intervals. At the initiation of the study, samples were collected at more frequent weekly intervals. After evaluation of the early data, it was decided that for most cases, biweekly resolution of water quality parameters on a routine basis was adequate. The exception to this rule was at the outfall station at the SEZ Dairy site. The intermittent nature of the discharge from the milking barn waste lagoon management system required frequent monitoring to gain adequate resolution of the input of the operation on quality of discharge from the watershed. Samples for water quality analyses were collected at this station on a daily basis or more frequently as desired.

Biweekly water quality samples were collected manually by the grab method in a 3.78 liter plastic bucket. Where more frequent samples were required, they were collected by the use of two types of Manning Environmental Corp. automatic water sampling devices. Each type of device had a 24-sample capacity and could be set to collect samples at a variety of frequencies ranging from every four minutes to daily if so desired. Samples, when collected, were divided into two aliquots, each placed in clean Nalgene bottles. The first aliquot was immediately capped and preserved by placing it on ice. The second aliquot was filtered through Nucleopore Corp. 04 um polycarbonate filters using a hand operated Millipore syringe filtering apparatus. The filtrate was also capped and placed on ice. All samples were kept cool during transport to the laboratory and were subsequently held at 4 degrees C while stored in the laboratory prior to chemical analysis.

STORM EVENT SAMPLING - Storm events and other special case situations, where getting or keeping personnel on location was awkward or inconvenient due to logistics, were handled by using automatic sampling devices. One type of sampling device manufactured by Manning Corporation (S-6000) was mated to a refrigerated sample storage compartment and thus required a 110-volt power supply for operation. These units were installed at the outfall stations at both SEZ Dairy and at Ash Slough. These devices were serviced routinely on a twice- weekly basis. The other type of automatic sampling unit Manning (S-4040) was a smaller, portable device powered by a rechargeable 12-volt lead-acid battery. These units were located at the flow monitoring critical depth flumes at Ash Slough and equipped with flow probe devices designed to kick off the device and initiate water sampling given a rising water stage accompanying the beginning of a "storm event". These devices were serviced as often as possible during such events. The time interval between visits was such that rarely, if ever, was the sampler serviced less than twice per week during the duration of any event.

Samples collected in these devices were unpreserved and unrefrigerated. In order to determine if the lack of preservation influenced or altered the nutrient species of interest, a study was designed to compare what changes, if any, occurred in nutrient concentrations of samples from refrigerated versus nonrefrigerated containers over time. The experimental media were stations where nitrogen and phosphorus concentrations were comparatively low, moderate, and high. A 3.78 liter container of each was placed in the laboratory's sample storage refrigerator and similar 3.78 liter containers of each were placed in a heat-stressed environment established by confining them in the housing of one of the portable water samplers placed outdoors in an unshaded area. The test was conducted during the month of July. This latter group was subjected to daytime temperatures well in excess of 38 degrees C. One sample from each container was collected daily and analyzed for nitrogen and phosphorus concentrations. The experimental results suggested that samples could be left in the field in an unpreserved, unrefrigerated conditions for up to one week with little, if any, change in total N concentrations. There was a slight trend towards conversion of organic forms to nitrate and ammonia, especially in the most nutrient-rich media. Total and ortho P concentrations remained unaffected. Given these results and a twice-weekly frequency of servicing, it is assumed that N and P concentrations from samples collected by the portable automatic devices remained representative of conditions as they existed at the time the sample was collected.

With the exception of the north channel at Armstrong Slough, flow in each conveyance channel was generated entirely by surface runoff from rainfall and a subsequent but definite amount of seepage of resulting shallow groundwater into the channel. Once the shallow groundwater table dropped below the elevation of the channel bottom, the conveyance channels became totally dry. The north channel at Armstrong Slough never experienced this phenomenon, however, as groundwater used for irrigation of the approximately 225 ha citrus operation at the upper end of the watershed was continually discharged during the dry seasons.

The Ash Slough site was most sensitive to runoff from rainfall events. The response time of runoff from the watershed and the cessation of flow following rainfall was the most rapid here of all the sites. The intermittent nature of water in the channels and the marsh necessitated establishing an intensive storm event monitoring program where samples were taken at least once daily during discharge events.

A storm event was defined here as occurring at the onset of runoff from the contributing watersheds into the detention/retention marsh until the cessation of outflow from the marsh. An event, then, was the result from either a single intensive period of rainfall or a longer-term affair composed of multiple rainfall events contributing to a period of continuous inflow to and/or discharge from the marsh.

RAINFALL - Samples of rainfall were collected for quality analysis at both the S-65D lock and water control structure on the Kissimmee River and at the District's Okeechobee Field Station. Rainfall quality data was available from a third location in the study area (S-65B lock and water control structure on the Kissim-mee River) and was incorporated into the rainfall quality analysis. Data from these three stations were used in determining "typical" concentrations of nutrient species in rainfall on the study area.

Bulk precipitation (wet and dry fall) was collected in 500 ml Nalgene bottles placed inside a protective wooden box. A 15 cm diameter Nalgene funnel protruded out of the top of the box and was rimmed by a serrated plastic ring to discourage birds using the device as a perch. The collecting boxes were supported approximately 5-6 feet above ground in open areas free ifrom interference from buildings, vegetation, or any other tall structures. Rainfall collected in the devices was composited over the week by emptying the collection bottle following each event into a large refrigerated Nalgene storage bottle which was then sent to the District's laboratory facilities for chemical analysis.

LABORATORY

All laboratory analytical procedures were in accordance with EPA guidelines in Methods for Chemical Analysis of Water and Wastes, 1979 Ed., and the American Public Health Associations Standard Methods, 14th Ed.

Physical parameters monitored were pH, color, turbidity, and specific conductance. Chemical parameters were nitrogen species (nitrate, nitrite, ammonia, total Kjeldahl nitrogen) and phosphorus species (ortho and total).

Color was measured by comparing the subject water sample spectrophotometrically against platinum/cobalt standards. Sample pH was determined using a Corning® Model 130 pH meter and combination electrode. Specific conductance was measured by use of a Radiometer® manual temperature compensating conductivity meter. Turbidity was determined with a Hach® Turbidimeter Model 2100A.

Nitrogen and phosphorus species were evaluated colorimetrically using automated procedures on a Technicon AutoAnalyzers®.

Quality control for precision and accuracy was maintained by frequent periodic calibration of equipment with standard solutions as well as repeat samples and standard addition samples prepared by mixing randomly selected samples with a known standard solution and determining percent recovery. In addition, split samples were analyzed at both the Okeechobee and West Palm Beach laboratory facilities and the results compared.

Triplet samples at randomly chosen locations were collected in the field during routine sampling periods. These were used to maintain a check on potential variation due to sampling error.

Specific details of laboratory analytical and quality control procedures are described in Goldstein et al, 1980.

DATA PROCESSING

Hydrological and water quality data collected during the Upland Demonstration Project were subject to the District's rigorous review and verification processes to insure that data finally put on permanent computer storage would be accurate and free of any errors due to analytical or transcription processes. All data collected as part of this project are permanently stored in the District's central computer facilities.

SECTION IV
RAINFALL ANALYSIS

INTRODUCTION

The following discussion describes the impact of atmospheric contributions as sources of nitrogen and phosphorus on the watersheds of the Upland Demonstration Project study sites. The impacts of these sources during the study years, October 1979 through September 1982, are described, and an attempt is made to put this information into context with historical rainfall data on these watersheds. Rainfall loading rates are calculated for each study watershed in the project area and applied in such a manner as to provide an estimate of total nutrient loads on the study watersheds that are necessary to compute land use nutrient budgets.

METHODS

An initial effort was made (Goldstein, 1981) to evaluate aeolian contributions to the Upland D/R Project site watersheds and their subsequent impacts on water quality data collected over the years 1979 and 1980. The rationale and method described in that report will be followed here.

An effort was made to determine how rainfall during the subject study period compared with what could be considered "normal" based on historical records. Monthly rainfall quantity records were obtained for eleven permanent SFWMD monitoring network stations in the vicinity of the Upland D/R Project sites for their entire period of record (Table IV-1). Records from stations clustered in the immediate vicinity of each project site were evaluated as discrete groups to arrive at historical monthly and annual rainfall quantity totals typical of the specific project site area (Table IV-2). The rainfall totals observed at the project sites during the study period (Tables IV-3a through IV-3c) could be compared with this "historical" record and an evaluation could be made as to whether or not these data were consistent with long-term patterns. These comparisons are graphically depicted in Figures IV-1 through IV-5.

Rainfall quality was obtained by collecting samples for quality analysis at stations located at structures S-65B and S-65D on the Kissimmee River and at the SFWMD's Okeechobee Field Station. The samples were collected at least once per week and frequently more often. Analyses for nitrogen and phosphorus parameters were carried out at the SFWMD's water chemistry laboratory in West Palm Beach. These data for each parameter were averaged. A Students t-test was run to determine if differences observed among the sample means at the three monitoring stations were significant. Though the mean

TABLE IV-1.

TOTAL MEAN ANNUAL RAINFALL ON UPLAND D/R PROJECT AREA - HISTORICAL PERIOD OF RECORD

SFWMD Rainfall Network Monitoring Station	Period of Record	Total Years
S-68	1965-82	18
El Maximo Ranch	1972-82	11
Micco Bluff	1972-82	11
Basinger	1972-82	11
Peavine Trail	1972-82	11
Tick Island	1974-82	9
Maxcy South	1974-82	9
S-65	1965-82	18
S-65A	1965-82	18
S-65C	1966-82	17
Okeechobee Field Station	1960-82	23
Brighton	1960-82	23
Okeechobee Forest Service	1969-82	14

TABLE IV-2. HISTORICAL MEAN MONTHLY AND ANNUAL RAINFALL AT STATIONS IN THE VICINITY OF UPLAND PROJECT SITES

Mean Monthly Rainfall Total (Centimeters)

SFWMD Rainfall Monitoring Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual Rainfall Total
Armstrong Slough and Peavine Pasture Sites													
El Maximo	5.66	5.54	5.49	5.69	17.12	16.51	19.81	14.45	16.87	5.54	5.36	4.11	122.15
S-65	5.99	7.85	6.63	5.69	13.94	20.73	20.40	17.27	17.25	4.47	4.47	5.16	134.55
S-65A	4.98	7.24	5.79	4.11	12.45	19.18	19.02	18.21	16.97	8.26	3.40	3.94	123.55
Historical Mean Rainfall for Study Site (x)	5.54	6.88	5.97	5.16	14.50	18.81	19.74	16.64	17.03	7.66	4.41	4.40	126.75
SEZ Dairy													
Okeechobee Field Station	4.39	6.50	6.32	4.60	12.85	18.82	16.61	17.83	14.96	8.51	5.05	4.19	120.63
Okeechobee Forest Service	6.02	7.70	9.27	4.80	17.68	22.05	25.04	22.07	19.33	6.55	7.72	5.74	154.27
Historical Mean Rainfall for Study Site (x)	5.21	7.10	7.80	4.70	15.42	20.44	20.83	19.95	17.15	7.53	6.39	4.97	137.45
Wildcat Slough													
S-65C	5.03	6.91	7.14	5.18	13.82	19.63	18.06	15.34	16.00	6.60	4.34	4.22	122.27
Brighton	5.13	6.30	6.99	4.90	11.68	22.33	18.34	17.78	17.37	8.56	4.70	5.08	129.16
S-68	4.60	5.56	5.51	2.79	10.62	14.61	14.25	15.06	14.58	6.15	3.30	3.20	100.23
Historical Mean Rainfall for Study Site (x)	4.92	6.26	6.55	4.29	12.04	18.86	16.88	16.06	15.98	7.10	4.11	4.17	117.22
Ash Slough													
Mico Bluff	3.96	6.45	5.44	4.45	12.80	17.53	15.32	15.70	11.33	3.76	4.72	4.24	105.70
Bassinger	4.42	5.33	5.64	5.46	14.86	13.18	15.93	14.66	15.98	5.08	4.67	3.86	109.07
Maxcy South	6.10	7.80	6.07	3.38	15.62	17.09	22.10	13.34	16.76	5.74	6.02	6.32	126.34
Historical Mean Rainfall for Study Site (x)	4.83	6.53	5.72	4.43	14.43	15.93	17.78	14.57	14.69	4.86	5.14	4.81	113.70

TABLE IV-3a.

MONTHLY AND ANNUAL RAINFALL ON UPLAND DEMONSTRATION PROJECT SITES
October 1979 - September 1980 (Centimeters)

	Armstrong Slough	Ash Slough	Peavine	SEZ Dairy	Wildcat Slough
October	0.3	1.5	0	0.9	2.1
November	1.8	1.2	1.2	2.4	0.6
December	7.0	5.2	1.8	6.1	3.1
January	4.6	4.9	2.7	5.2	7.3
February	7.3	6.4	2.4	3.7	4.3
March	4.6	6.7	2.1	3.4	4.9
April	5.2	9.5	3.7	4.6	5.5
May	11.3	1.8	12.2	3.4	8.2
June	11.0	7.6	7.3	10.7	7.9
July	21.6	22.0	16.2	23.2	15.9
August	10.7	19.5	6.1	13.1	8.5
September	7.0	19.8	1.2	11.3	5.5
ANNUAL TOTAL	92.4	106.1	57.0	87.8	73.8

TABLE IV-3b.

MONTHLY AND ANNUAL RAINFALL ON UPLAND DEMONSTRATION PROJECT SITES
(October 1980-September 1981(Centimeters)

	Armstrong Slough	Ash Slough	Peavine	SEZ Dairy	Wildcat Slough
October	1.8	1.2	0.9	0.9	1.2
November	8.2	9.8	6.4	10.1	8.2
December	2.7	2.1	4.0	1.8	1.8
January	0.6	0	0	0.6	0.3
February	5.8	7.0	5.8	4.6	6.1
March	3.4	1.8	4.3	0	1.8
April	0	0	0	0	0.3
May	7.0	3.7	4.3	8.8	5.8
June	11.3	5.8	6.4	15.5	14.6
July	11.6	12.8	10.1	16.8	22.6
August	28.7	17.4	15.0	19.5	15.5
September	14.9	11.0	14.3	17.7	8.5
ANNUAL TOTAL	96.0	72.5	71.3	96.3	86.9

TABLE IV-3c.

MONTHLY AND ANNUAL RAINFALL ON UPLAND DEMONSTRATION PROJECT SITES (October 1980-September 1981(Centimeters)

	Armstrong Slough	Ash Slough	Peavine	SEZ Dairy	Wildcat Slough
October	5.8	1.5	4.3	0.3	1.8
November	3.7	2.3	7.9	0.3	2.7
December	0	0	0	0	0
January	3.7	3.1	2.4	0.6	6.4
February	7.0	6.7	2.1	0	7.0
March	11.6	4.6	9.2	13.1	17.4
April	8.5	7.6	10.1	10.7	11.4
May	12.2	8.8	13.7	16.5	9.1
June	31.7	16.8	12.8	23.2	20.4
July	12.2	13.7	17.8	18.0	10.4
August	25.9	15.5	15.2	20.4	9.1
September	18.6	19.2	23.6	22.0	7.0
ANNUAL TOTAL	140.8	99.8	118.2	125.0	102.8

concentrations of nitrogen and phosphorus were consistently highest at S-65B and lowest at the Okeechobee Field Station, no significant difference was found at the 95 percent level. To obtain an estimate of rainfall contribution to watershed nutrient budgets, the mean concentration of each parameter (obtained from summing the individual mean concentrations of that parameter at each of the three stations) was considered "typical" aeolian input of that parameter in the Kissimmee River basin and Upland Demonstration Project sites.

Using this "typical" mean concentration of each parameter, monthly rainfall totals, and the surface area of each watershed, loading calculations were done to arrive at "estimated" nitrogen and phosphorus loading rates on monthly and annual bases, which then could be applied in computations of overall watershed nutrient budgets.

RESULTS

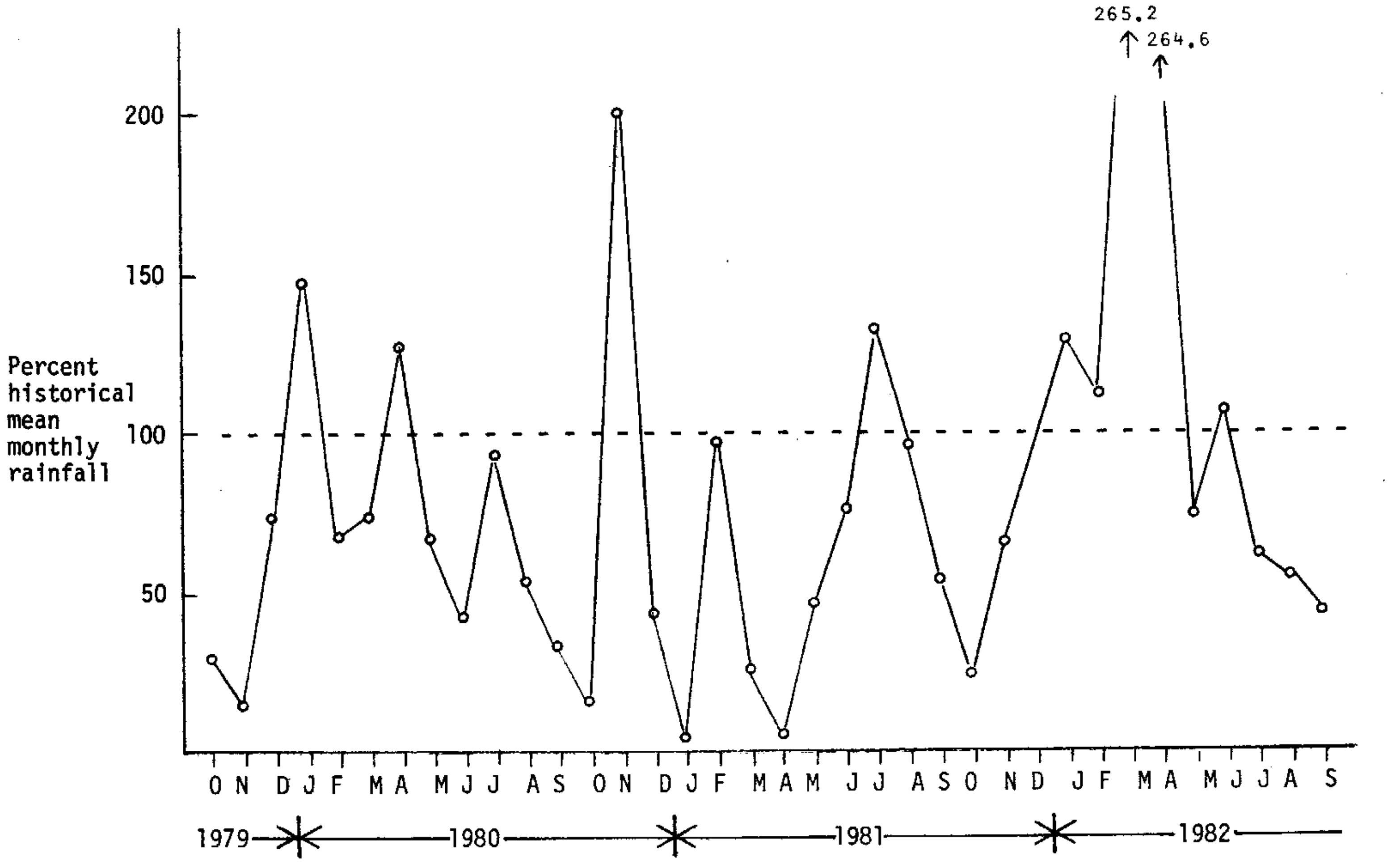
While earlier Upland Detention/Retention Project status reports dealt with a data set dating from April of 1979, this project completion document will emphasize those data collected between October 1, 1979 through September 30, 1982, which coincide with the USGS water year. The rationale for this is two-fold. The primary reason is that this allows the data set to conveniently be separated into three complete years, each consisting of a wet season and an antecedent dry season. The second reason is that the use of the water year allows the data to be evaluated in a context that is consistent with a commonly accepted practice.

Cases where meteorological events antecedent to October 1979 may be of some interest are referred to where appropriate in the various discussion sections. For all other purposes, the subject period of the study addressed in this report will include only the time within the above specified dates.

RAINFALL QUANTITY

Wildcat Slough - Mean annual rainfall in and around the Wildcat Slough study site over the historical period of record has averaged 117.2 cm. Average monthly total rainfall amounts over this period confirm the existence of a distinct wet seasonwhere monthly rainfall totals exceed 6.4 cm, and a dry season where monthly rainfall totals are less than 6.4 cm. The wet season runs from May through October,while the remainder of the year constitutes the dry season. Historical average monthly rainfall amounts peak in June at about 18.5 cm. During the 36-month period from October 1979 through September 1982, monthly rainfall totals at the site were greater than historical means on only 9 occasions (Figure IV-1). Total monthly rainfall was less than mean monthly totals on 26 occasions. Annual rainfall totals during the three years of the study were 73.8, 86.9, and 102.8 cm, or 62.9, 74.1, and 87.7 percent of

Figure IV-1. Wildcat Slough - Percent Historical Average of Monthly Rainfall During Upland D/R Project.



the historical normal amount for the area. All but one of the monthly totals during each of the three wet seasons was below historical averages. On the other hand, monthly rainfall totals during the "dry" months of early 1982 were above average with March and April being significantly wetter mnonths than normal.

In general, the rainfall conditions on the Wildcat Slough watershed during the course of this study were characterized by subnormal amounts, particularly during the first two years. The greatest quantities of rainfall on the watershed did occur during what is considered the wet season of each year. However, each wet season was subnormal for rainfall when compared to the historical record.

Ash Slough - Mean annual rainfall calculated from monitoring stations in the vicinity of the Ash Slough study site totaled 113.7 cm. Historical mean monthly rainfall totals depict a distinct five-month wet season (May through September) when monthly rainfall totals average greater than 14.7 cm. During the remaining seven months, mean rainfall totals fail to exceed 5.5 cm. During the three years of study, monthly rainfall totals have exceeded historical means on 15 occasions (Figure IV-2). During 20 of the remaining 21 months, total rainfall was substantially less than average. Annual rainfall totals for the three years were 106.1, 72.5, 99.8 cm or 93.3, 63.8, and 87.8 percent of the historical mean totals. Rainfall totals at Ash Slough during 1981 reflected the record drought recorded throughout south Florida during this period. Rainfall for the calendar year on the site was 59.4 cm, or approximately 51.3 percent of the historical mean. The impact of the 1981 drought on the study was greatest at this site, as the lack of rainfall prevented any evaluation of efficiency of the wetland detention system to remove nutrients from pasture runoff during that year.

Armstrong Slough - Historical mean annual rainfall at the monitoring stations around the Armstrong Slough site is 126.7 cm. The typical south Florida wet/dry seasonal pattern as described earlier is repeated again here. May through September constitutes the wet months with average monthly rainfall totals ranging from 14.9 cm to 20.0 cm. Mean monthly rainfall for the remaining seven months does not exceed 7.2 cm. Annual rainfall measured at the study site was below normal for the first two years, but was slightly in excess of normal during the last year of the three-year study. Below normal monthly totals occurred during 24 of the 36 months of record (Figure IV-3). On only one occasion during the 1981 drought was total monthly rainfall at or above the historical mean. Annual rainfall at Armstrong Slough during the study was 92.4, 96.0, and 140.8 cm, or 72.9, 75.8, and 111.1 percent of historical averages.

Peavine Pasture - Historical rainfall monitoring records for the Peavine Pasture area are the same as those obtained at the SFWMD rainfall monitoring stations described for Armstrong Slough. The annual and monthly rainfall totals and trends obtained over the historical period of record are described in the above section. Annual rainfall totals measured at the study site were below historical averages for the three years (57.0, 71.3, and 118.2 cm, or 45.0, 56.3, and 93.3 percent of the norm). Monthly rainfall totals were less than historical averages during 31 of the 36 months study period (Figure IV-4). There was only one month (September 1982) during the wet seasons of the three year study when rainfall exceeded the historical monthly average.

SEZ Dairy - Historically, the area including the SEZ Dairy has been the wettest of the Upland D/R Project study sites. The historical mean annual rainfall total is 137.5 cm. May through September are the wet months, with historical monthly mean rainfall totals ranging from 15.5 cm to 21.2 cm, while average monthly rainfall totals for the remainder of the year range from 4.2 to 7.7 cm. During the period of study, annual rainfall totals at the site were 87.8, 96.3, and 125.0 cm, or 63.9, 70.1, and 90.9 percent of the historical norm. Monthly rainfall totals were less than historical averages during 23 of the 36 months. Five months were at or near normal and eight had above normal rainfall (Figure IV-5). During 1981, total rainfall exceeded historical averages on only one occasion. During three months of the year, no rainfall at all was recorded at the site.

Summary - Rainfall patterns during the study were typical of the south Florida area in that a very distinct two season (wet and dry) regime was manifest. The study period was atypical from the standpoint that rainfall amounts, particularly during the first two years, were less than historical averages. The major shortfall in rainfall occurred during the "wet" season months. Rainfall amounts during the last year of the study approached historical norms and could be considered more typical than those of the preceding two years.

Study results should be scrutinized under the light that they represent the area of the spectrum between one extreme (drought) and a more average situation. Unfortunately, the opposite extreme (annual rainfall significantly in excess of the historical mean) did not occur and thus cannot be evaluated. There was, however, the period of August and September 1979, when rainfall associated with

Figure IV-2. Ash Slough - Percent Historical Average of Monthly Rainfall During Upland D/R Project.

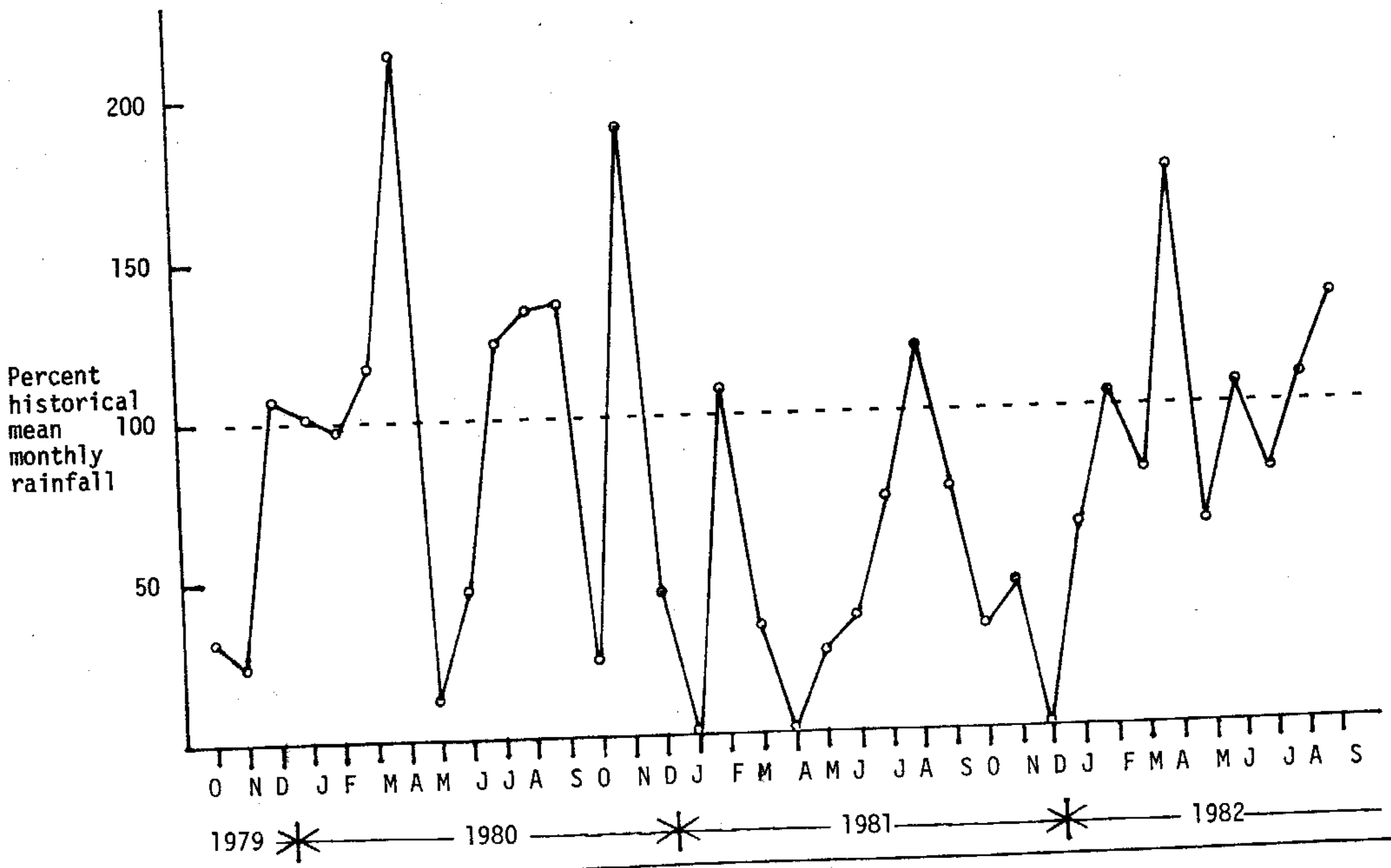


Figure IV-3. Armstrong Slough - Percent Historical Average of Monthly Rainfall During Upland D/R Project

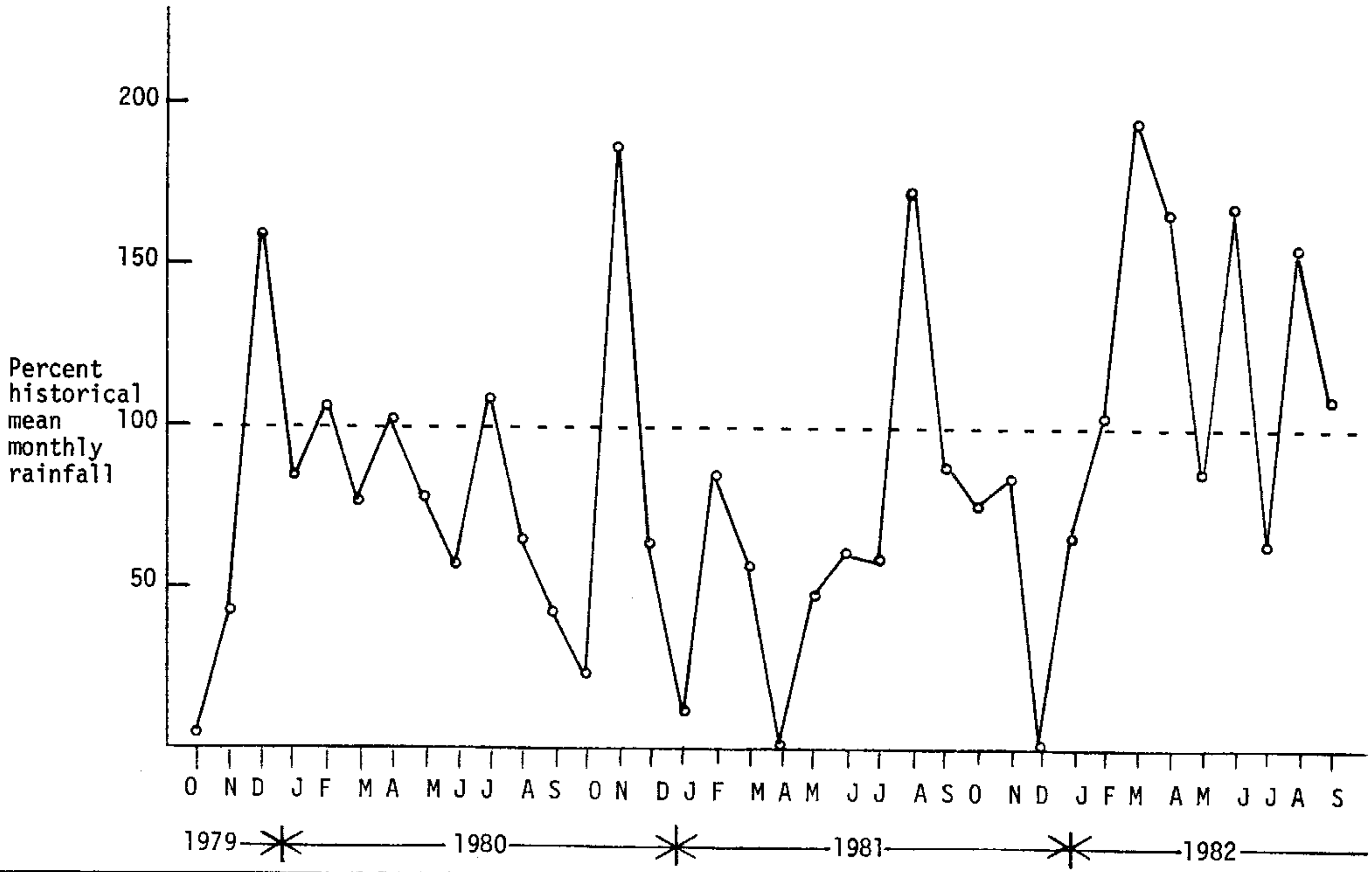


Figure IV-4. Peavine Pasture - Percent Historical Average of Monthly Rainfall During Upland D/R Project.

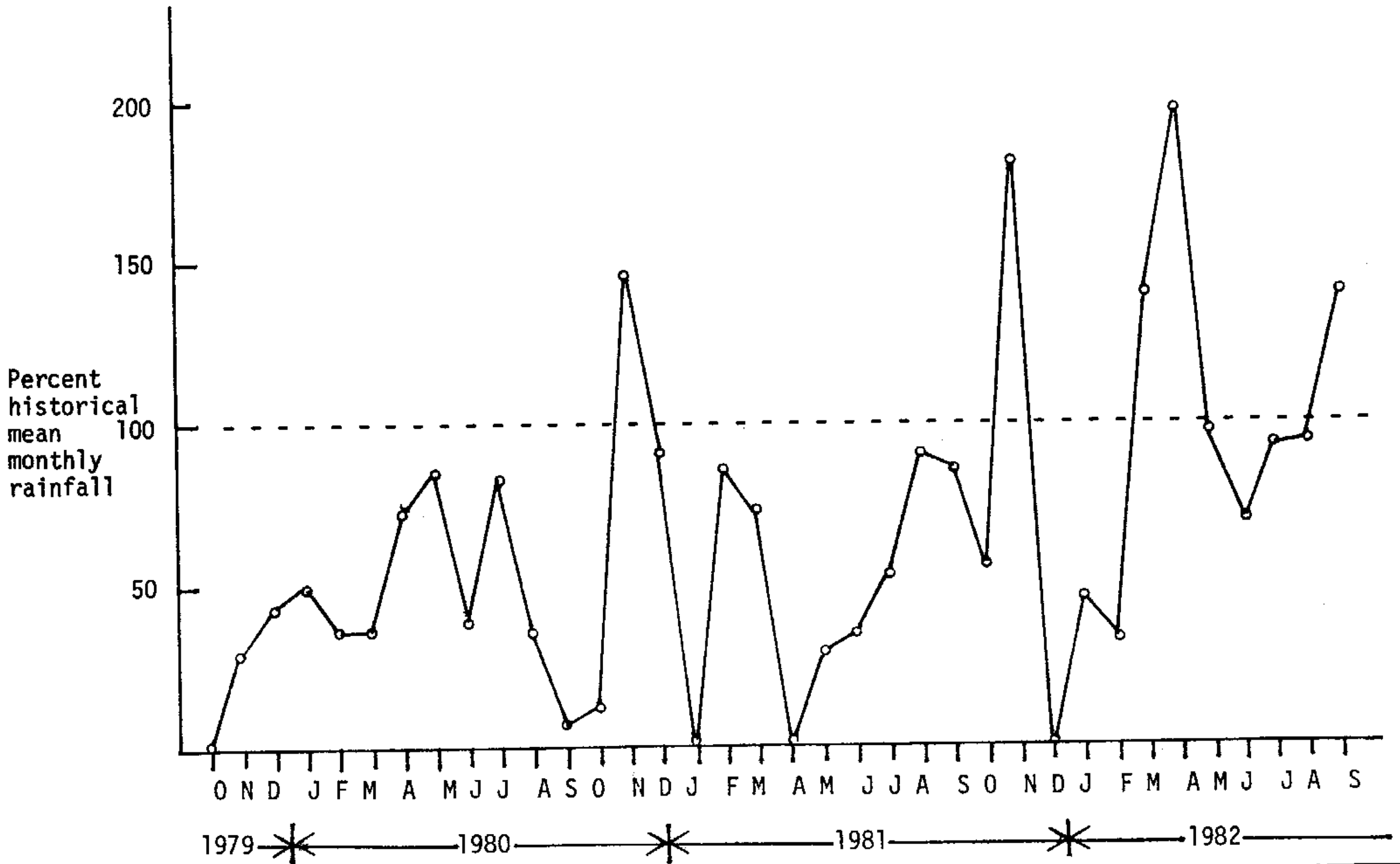
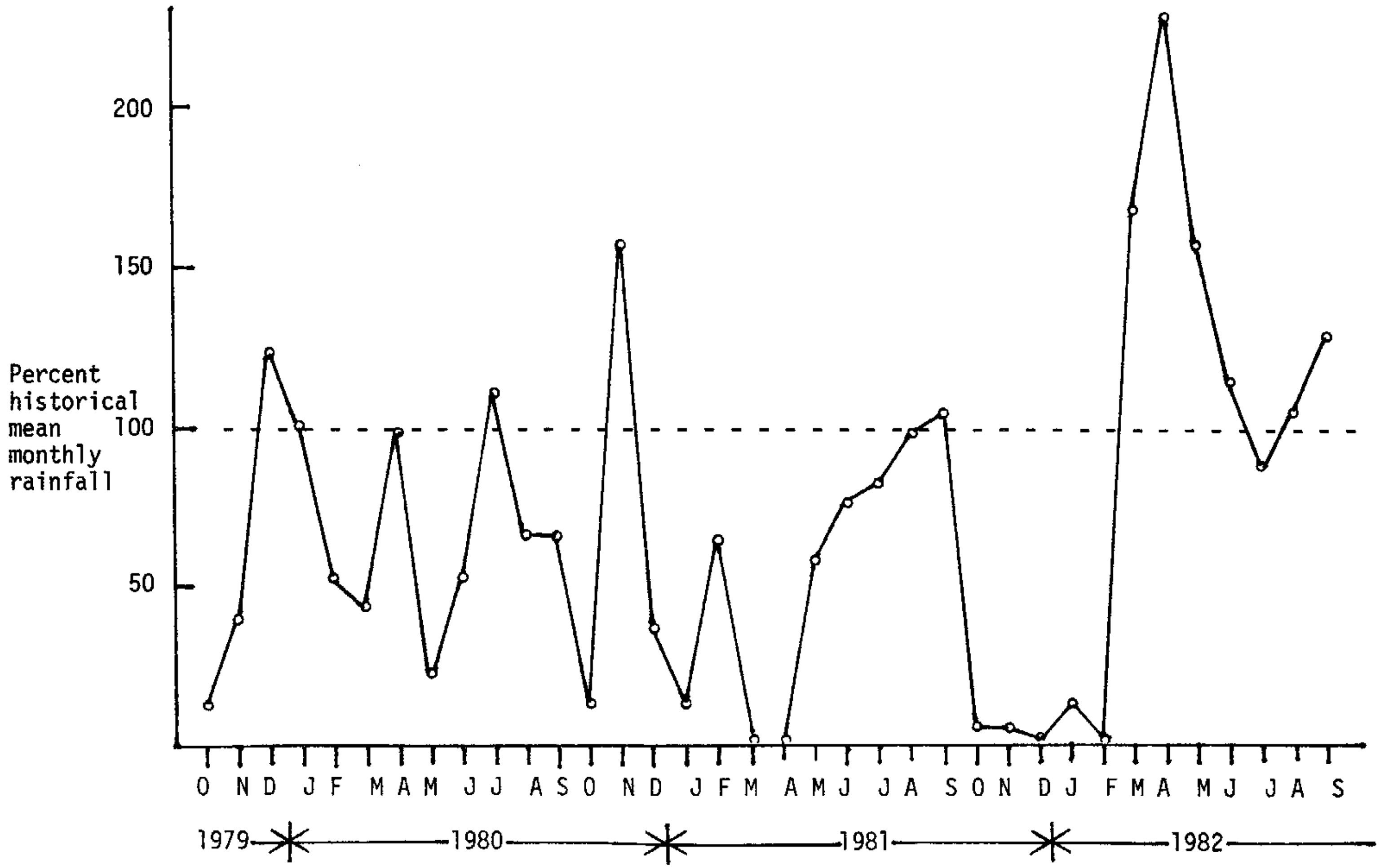


Figure IV-5. SEZ Dairy - Percent Historical Average of Monthly Rainfall During Upland D/R Project.



Hurricane David and other tropical disturbances did result in a prolonged period during which the study watersheds received rainfall and generated runoff far in excess of normal amounts. Since this event occurred just prior to the subject period of record for this study, its impacts, if any, on these results is minimum.

RAINFALL QUALITY

As previously described, rainfall quality data typical of the study area was obtained by compiling quality data from three stations located in the Upland D/R Project area (S-65B and S-65D, both located on the Kissimmee River (C-38 canal), and the SFWMD's Okeechobee Field Station). Mean concentrations, ranges, and number of data points for each parameter of interest are depicted in Table IV-4. "Rainfall", as used here, is defined as the total of all wet fall and dry fall (dust, debris, etc.) components that accumulate in the rainfall collection bottles.

As a trend, rainfall quality as measured by mean concentrations of nitrogen and phosphorus species appears to become cleaner as one moves south in the Upland Project study area. Statistical comparison of the mean concentrations of each parameter at each station with the mean concentrations of similar parameters at each of the other two stations by using a Student's t-test failed to show any statistically significant differences.

Given the absence of any better method, "typical" concentrations of nitrogen and phosphorus species that could be consistently attributed to the rainfall over the project area were arrived at by averaging the mean value of each parameter of interest among the three monitoring locations within the project area. Concentrations of nitrogen and phosphorus parameters in rainfall considered "typical" in the Upland D/R Project area are: 0.67 mg/l dissolved inorganic nitrogen (NO_x + NH_4), 1.54 mg/l total nitrogen (both as nitrogen), 0.060 mg/l ortho phosphorus, and 0.096 mg/l total phosphorus (both as phosphorus). Dissolved forms of N and P make up roughly one-half and two-thirds of the total N and total P loads, respectively. This suggests that contributions of these nutrients as particulates (dry fall and washout) is of lesser but significant importance.

Though there exists a wide range between the maxima and minima in the individual station data, mean concentrations at each station compare favorably with other rainfall quality data appearing in the literature (Table IV-5), particularly with other data collected in the south Florida area. In an extensive analysis of the climatology of the Kissimmee River - Lake Okeechobee watershed, Echternacht (1975) concluded that, in general, minimum nitrogen and phosphorus concentrations occurred during the wet season. He also suggested that the large degree of variability noted in measurements of individual parameters was due to the temporal/spatial nature

TABLE IV-4. RAINFALL QUALITY DATA SUMMARY

	NO_x + NH_4	Total N	Ortho P	Total P
S-65D (1979-1982)				
Mean	0.75	1.63	0.073	0.120
Range	0.06 - 3.30	0.24 - 5.52	0.004 - 0.271	0.010 - 0.496
Number of Observations	72	72	67	68
S-65B (1974-1982)				
Mean	0.73	1.85	0.074	0.118
Range	0.03 - 3.59	0.21 - 6.50	0.002 - 0.232	0.003 - 0.549
Number of Observations	186	154	188	183
Okeechobee Field Station (1975-1982)				
Mean	0.52	1.14	0.033	0.050
Range	0.04 - 3.16	0.21 - 4.73	0.002 - 0.402	0.005 - 0.453
Number of Observations	95	81	95	90

TABLE IV-5

CONCENTRATIONS OF SELECTED NUTRIENT SPECIES REPORTED IN PRECIPITATION (mg/L)

Source	Location	NO_x	NH_4^+	Total N	Ortho P	Total P	Date of Collection
Nicholls & Cox, 1978	Harp Lake, Ontario Canada			1.91		0.105	1974
Haines, 1976	Georgia Coast		0.135	0.234			
Echternacht, 1975	Florida Peninsula		0.15 - 1.255		.002 - .074	.052 - .124	Summer, 1972
Zoltec, et al., 1979	Winter Garden, Florida				0.03	0.04	05/77 - 02/78
Zoltec, et al., 1979	Lake Apopka, Florida				0.008	0.014	03/78 - 05/79
Davis & Wisniewski, 1975	South Florida	.158 - .341				.003 - 1.428	07/74 - 09/74
Davis, 1981	South Florida		0.17 - 2.20		.002 - .200	.022 - .304	Range of Seasonal Averages 1972-73
Joyner, 1974	Lake Okeechobee			0.90		0.056	1969 - 70
Brezonik, et al., 1969	Central Florida		0 - 0.86		.002 - .230	.02 - .07	02/68 - 12/68
Present Study*	Kissimmee River Basin	.261 - .313	.24 - .65	1.10 - 2.42	.029 - .151	.046 - .220	1974 - 78

*Range of Mean Concentrations Observed at Rainfall Collection Stations in Project Study Area of the predominant rainfall patterns in the basin as well as the multiple potential sources of nutrients both in and outside of the watersheds. Analyses of the data collected at S-65D during the course of this study fail to show any statistically significant seasonal differences in either NO_x or total PO_4 concentrations. The aforementioned observation that these data suggested an apparent north to south gradient of decreasing concentrations of nitrogen and phosphorus in rainfall in the Kissimmee River basin does support the observations by Davis and Wisniewski (1975) of similar trends throughout the south Florida area.

LOADING RATES

Loading rates in kg/ha/yr that can be considered to occur naturally due to rainfall have been calculated for the Upland Demonstration Project sites. These rates are best estimates of "long-term" conditions as they were computed using both historical mean annual precipitation for the specific project area and typical mean concentrations of nutrient species of interest in rainfall. The rationale and methodology used to arrive at these figures is described earlier in this section. Typical expected annual loading rates of nitrogen and phosphorus on the project study watersheds are presented in Table IV-6.

Comparison of mean annual loading rates calculated for the Upland D/R Project sites with others found in the literature indicates that, on a per unit basis, total nitrogen and total phosphorus loadings in the Kissimmee River basin study area are generally of the same order of magnitude but somewhat greater than those calculated at many other locations (Table IV-7). In general, these data compare favorably with loadings calculated by Zoltec et al (1979) in a study done of an area just north of the Kissimmee Lakes basin in central Florida. Since loading rates for nutrients attributable to rainfall are a function of both rainfall amounts and rainfall quality, it is not surprising to find the best agreement with data collected at close proximity to the project area.

WATERSHED NUTRIENT LOADINGS

Using mean nutrient concentrations in rainfall and annual rainfall totals measured during the three subject years of the study, an estimate was made of total annual nutrient loading on each watershed in the Upland D/R Project area. These data are presented in Tables IV-8a through IV-8c.

TABLE IV-6.

TYPICAL HISTORICAL LOADING RATES ATTRIBUTED TO PRECIPITATION ON UPLAND D/R PROJECT STUDY SITES FOR ENTIRE PERIOD OF RECORD (kg/ha/yr)

	$NO_x + NH_{4+}$	Total N	Ortho P	Total P
Armstrong Slough	8.49	19.52	0.76	1.22
Ash Slough	7.62	17.51	0.68	1.09
Wildcat Slough	7.85	18.05	0.70	1.13
Peavine Pasture	8.49	19.52	0.76	1.22
SEZ Dairy	9.21	21.17	0.82	1.32

TABLE IV-7.

PRECIPITATION LOADING RATES FOR SELECTED NITROGEN AND PHOSPHORUS SPECIES REPORTED IN THE LITERATURE (kg/ha/yr)

Location	Total P	Ortho P	Total N	NH_4+	NO_3-	NO_x	Source
Lake Valencia	1.68		7.45	2.43			Lewis, 1981
Brazil, Amazon Basin	0.27		9.95	3.15	2.52		Lewis, 1981
Venezuela, Amazon Basin				21.4			Lewis, 1981
Africa, Uganda and West Coast	1.20		19.1	6.6	4.9		Lewis, 1981
Hubbard Brook, New Hampshire	0.06			2.26	4.3		Lewis, 1981
Como Creek, Colorado	0.26		4.80	1.04	1.62		Lewis, 1981
Ontario, Canada	0.32		6.35				Lewis, 1981
Ontario, Canada	0.744		16.00				Nichols and Cox, 1978
Mays Point, New York				2.12	0.38		Reuss, 1978
Winter Garden, Florida	0.496	0.392					Zoltec, et al., 1979
Lake Apopka, Florida	0.656	0.340					Zoltec, et al., 1979
Clermont, Florida			11.23	1.87		3.44	Zoltec, et al., 1979
Kissimmee Sites	0.94 - 1.73	0.46 - .084	12.9 - 25.5	-1.0 - 7.0			Goldstein, 1981

TABLE IV-8a.

ANNUAL NUTRIENT LOADS ATTRIBUTED TO RAINFALL ON UPLAND D/R PROJECT WATERSHEDS (kg)

OCTOBER 1979 - SEPTEMBER 1980

	ha	$NO_x + NH_{4+}$	Total N	Ortho P	Total P
Armstrong - North	3,036.0	18,785	43,178	1,682	2,691
Armstrong - South	1,012.0	6,262	14,393	561	898
Armstrong - Ungaged	244.0	1,510	3,470	135	216
Peavine Pasture	243.0	928	2,133	83	133
Ash - East	20.0	142	327	13	21
Ash - West	68.8	489	1,124	44	70
Ash - Ungaged	18.6	132	304	12	19
Wildcat - East	2,591.0	12,806	29,435	1,147	1,835
Wildcat - West	1,729.0	8,546	19,642	765	1,224
Wildcat - C-41A	2,108.0	10,419	23,948	933	1,493
SEZ Dairy	330.0	1,941	4,461	174	278

TABLE IV-8b.

ANNUAL NUTRIENT LOADS ATTRIBUTED TO RAINFALL ON UPLAND D/R PROJECT WATERSHEDS (kg)

OCTOBER 1980 - SEPTEMBER 1981

	ha	$NO_x + NH_{4+}$	Total N	Ortho P	Total P
Armstrong - North	3,036.0	19,530	44,890	1,749	2,798
Armstrong - South	1,012.0	6,510	14,963	583	933
Armstrong - Ungaged	244.0	1,570	3,609	141	226
Peavine Pasture	243.0	1,161	2,669	104	166
Ash - East	20.0	97	223	9	14
Ash - West	68.8	334	768	30	48
Ash - Ungaged	18.6	90	207	8	13
Wildcat - East	2,591.0	15,079	34,659	1,350	2,160
Wildcat - West	1,729.0	10,062	23,128	901	1,442
Wildcat - C-41A	2,108.0	12,268	28,198	1,099	1,758
SEZ Dairy	330.0	2,129	4,894	191	306

TABLE IV-8c.

ANNUAL NUTRIENT LOADS ATTRIBUTED TO RAINFALL ON UPLAND D/R PROJECT WATERSHEDS (kg)

OCTOBER 1981 - SEPTEMBER 1982

	ha	$NO_x + NH_{4+}$	Total N	Ortho P	Total P
Armstrong - North	3,036.0	28,642	65,834	2,565	4,104
Armstrong - South	1,012.0	9,547	21,944	855	1,368
Armstrong - Ungaged	244.0	2,302	5,291	206	330
Peavine Pasture	243.0	1,925	4,425	172	275
Ash - East	20.0	134	308	12	19
Ash - West	68.8	460	1,057	41	66
Ash - Ungaged	18.6	124	285	11	18
Wildcat - East	2,591.0	17,840	41,005	1,598	2,557
Wildcat - West	1,729.0	11,905	27,364	1,066	1,706
Wildcat - C-41A	2,108.0	14,515	33,633	1,300	2,080
SEZ Dairy	330.0	2,763	6,351	247	395

SECTION V
SURFACE WATER QUALITY STUDIES

INTRODUCTION

The question of how physical characteristics of the land and the cultural activities employed upon that land impact quality of rainfall generated surface runoff and its subsequent impact on receiving waters has received much recent attention (Omernik, 1977; Robbins, 1978; Wendt and Corey, 1980; Sharpley, et. al., 1982; Omernik, et. al., 1981; Novotny, 1980; Hill, 1981; Doran, 1981; Thomas and Crutchfield, 1974; USEPA, 1983). This question has been addressed in the south and central Florida area in studies by Gatewood and Bedient, 1975; Huber and Heaney, 1976; Dickson, et. al., 1978; Forbes, 1971; Hortenstein and Forbes, 1972; Shih, et. al., 1976; Allen, et. al., 1975, among others.

One of the goals of the Upland Demonstration Project has been to add to this body of knowledge, particularly addressing impacts of land uses that occur in the Kissimee River Valley and the Taylor Creek/Nubbin Slough basins. As noted earlier in this document, these land uses are predominantly beef and dairy cattle production. These operations span a range of cultural alterations of the land from virtually none (native range) through highly improved pasture (cleared, ditched for drainage, and cultivation of specifically desired pasture grasses), to intense land use by large dairy herds densely stocked in staging pasture areas in close proximity to milking barns.

This chapter will contain an analysis and discussion of both time series water quality parameter concentration data collected over a three to four year period of record and associated nutrient loading and export calculations for the five project study sites.

Attempts will be made to correlate these data with various seasons, land uses, or intensities of land use. Finally, runoff quality loading coefficients for the subject land uses under investigation will be estimated and compared with other data available in the literature.

General characteristics and uses of the five study sites have been discussed in detail in preceding sections of this report but are tabularized here (Table V-1) for ready reference.

TABLE V-1. UPLAND DEMONSTRATION PROJECT SITES - LAND USES

Study Site	Watershed	Size (ha)	Predominant Land Use	Cattle Density Cows/Acre
Wildcat Slough	East Watershed	2591	Native Range	.05
	West Watershed	1729	Native Range	.05
Peavine Pasture		243	Improved Pasture	.20
Armstrong Slough	North Watershed	3036	Improved Pastures, Citrus	.20
	South Watershed	1012	Native Range Improved Pastures	.20
Ash Slough	East Watershed	20.2	Improved Pasture	.33
	West Watershed	68.8	Improved, Ditched Pastures	.33
SEZ Dairy	Holding Pasture	121.5	Cattle Holding, Staging Area	1.63
	Hay Pasture	202.4	Hay, Heifer Grazing	.40

ARMSTRONG SLOUGH - NORTH

Time Series Data

Two distinct watersheds were monitored at the Armstrong Slough site. The larger northern tributary is a dredged drainage channel that continually conveyed some base flow discharge as well as stormwater runoff from a 3,036 ha watershed. Given the physical characteristics of the land, general lack of topographic relief, and drainage systems interconnected with other major water conveyance channels (notably Skeeter Slough to the north and Pine Island Slough to the south) the exact boundaries of this watershed are indeterminable. The 3,036 ha estimate is thought to be a fairly accurate estimation of the land surface area that under most circumstances would be the major if not sole contributor of flow to the Armstrong Slough north channel. Discussions with the landowner on his observations of flow directions in the channels have verified that this estimate is reasonably accurate. The watershed land use is divided into approximately 227 ha (7.5 percent of land area) of citrus groves and 587 ha (20.0 percent of land area) of intensively ditched and drained improved pasture. The remainder is predominantly improved pasture interspersed with low isolated wetlands. Cattle are grazed on the ditched pasture and other areas that are not utilized for citrus. The land owner (Latt Maxcy Corp.) runs approximately 1,400-1,500 head of livestock on this watershed.

During the course of this study, typical fertilization practices included applications of high N fertilizers to citrus three to four times annually. Typical formulations were 18-0-27, 15-0-22, and 12-5-18. Applications were made in such a manner as to provide about 250 pounds of elemental nitrogen per acre each year (approximately 255 kg/ha). A more balanced fertilizer, such as 16-4-8, was applied to improved pastures on the average of once every two to three years.

Time series water quality data plotted simultaneously with measured discharge from the watershed are presented in Figures V-1 through V-4.

Extremes in rainfall conditions on the watershed were experienced during the study period of record. Hurricane David and intense rains that preceded it in August of 1979 contributed to a large pulse of discharge during the latter part of that year's wet season. Following the hurricane, south and central Florida began one of the most severe droughts on record. From October 1979 through August 1981, discharge from the watershed remained at low levels (as little as .10 cfs) with a few minor pulses during 1980. The drought was temporarily broken in August-September of 1981 with a significant increase in discharge due to stormwater runoff. The "wettest" year of record for the site was 1982 when a continual series of rainfall events resulted in a series of pulses of continual runoff from this watershed throughout the wet season.

Turbidity (Figure V-1) remained relatively low and constant at the monitoring location (station 2) through 1979-80 and most of 1981 (typically 2.1 - 2.2 NTUs). Turbidity levels increased in magnitude (average 4.5 NTUs) and variability in November 1981 and through the 1982 wet season, when they sometimes approached levels almost three times greater than those noted during the previous two years. No distinct seasonal trends were evident nor could increased turbidity be correlated with single discharge events of increased flow past the monitoring point. The higher and more variable turbidity did seem to be associated with the continual higher quantities of discharge (twice that of previous years) that were noted in 1982.

An increase in color levels seems to be positively correlated with increased discharge (Figure V-1). Rainfall may serve to flush organic acids and other color producing dissolved constituents from the soils. Mean annual color levels were twice as high in 1982 as in previous years when discharge was approximately double that of the first two years of study (Figure V-5).

With the exception of two aberrant data points in 1982, pH remained constant and near neutral. Mean annual pH values were characteristically neutral to slightly acidic (Figure V-2). A suggestion of a trend toward slightly lower pH during periods of significantly increased flow can be noted. This may b due in large part to the slightly acidic nature of th area rainfall that generates this increased runoff fro the watershed.

Conductivity follows an inverse trend of lo er levels occurring during periods of high discharge and higher levels occurring during periods of low and base flows (Figure V-2). This is explained by the increase in groundwater used during the dry season for irrigation of the citrus acreage in the upper portion of the watershed. Groundwater is probably the major contributor of base flow from the watershed.

With the exception of a brief period in late July and early August of 1981, inorganic N concentrations (Figure V-3) were near or below detection limits. The increased inorganic N concentrations noted at that time could be attributed to application of high N fertilizer on the citrus groves during this period.

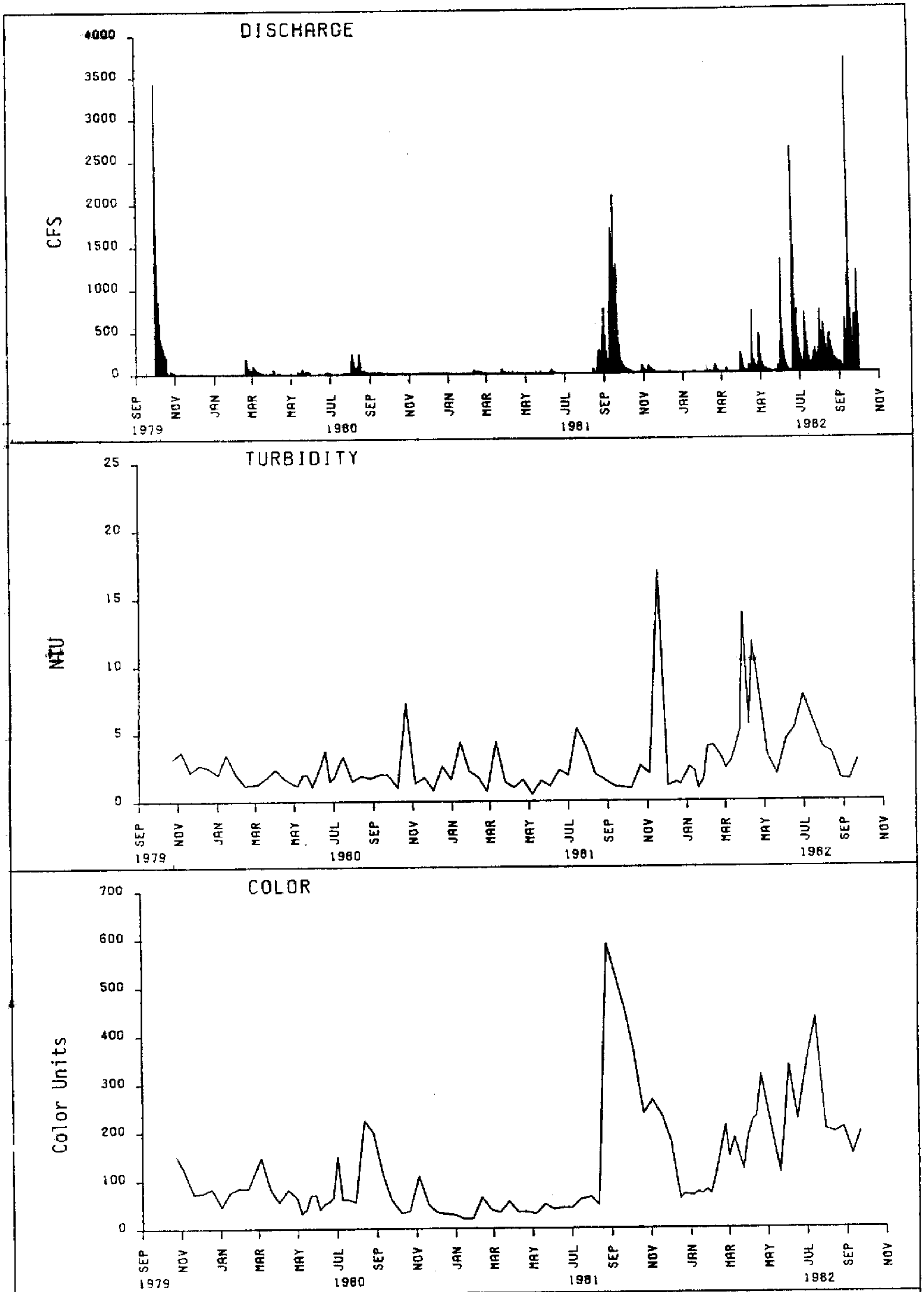


Figure V-1. Time Series Concentrations Armstrong Slough-North Watershed (1979-1982) Station 2.

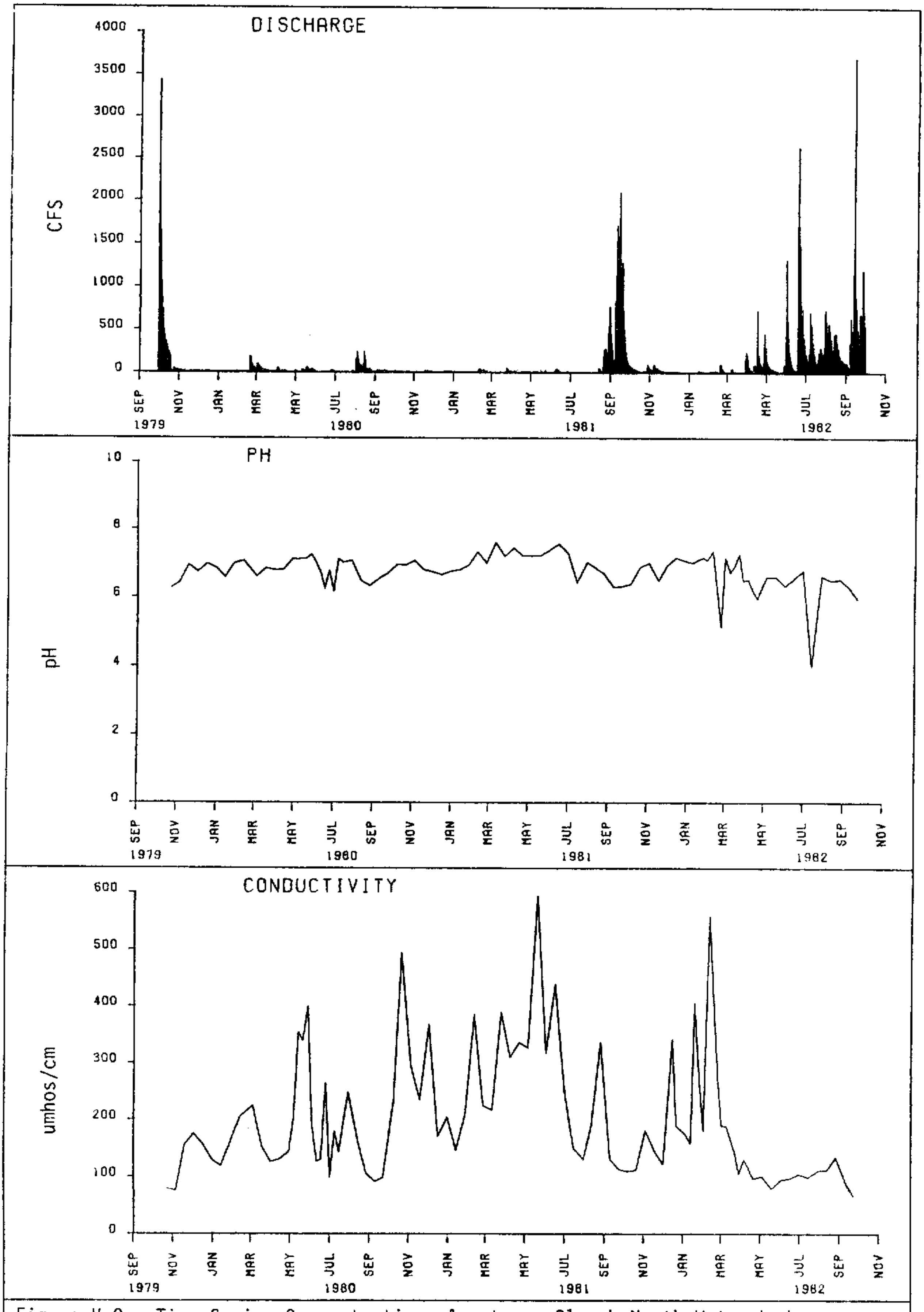


Figure V-2. Time Series Concentrations Armstrong Slough North Watershed (1979-1982) Station 2.

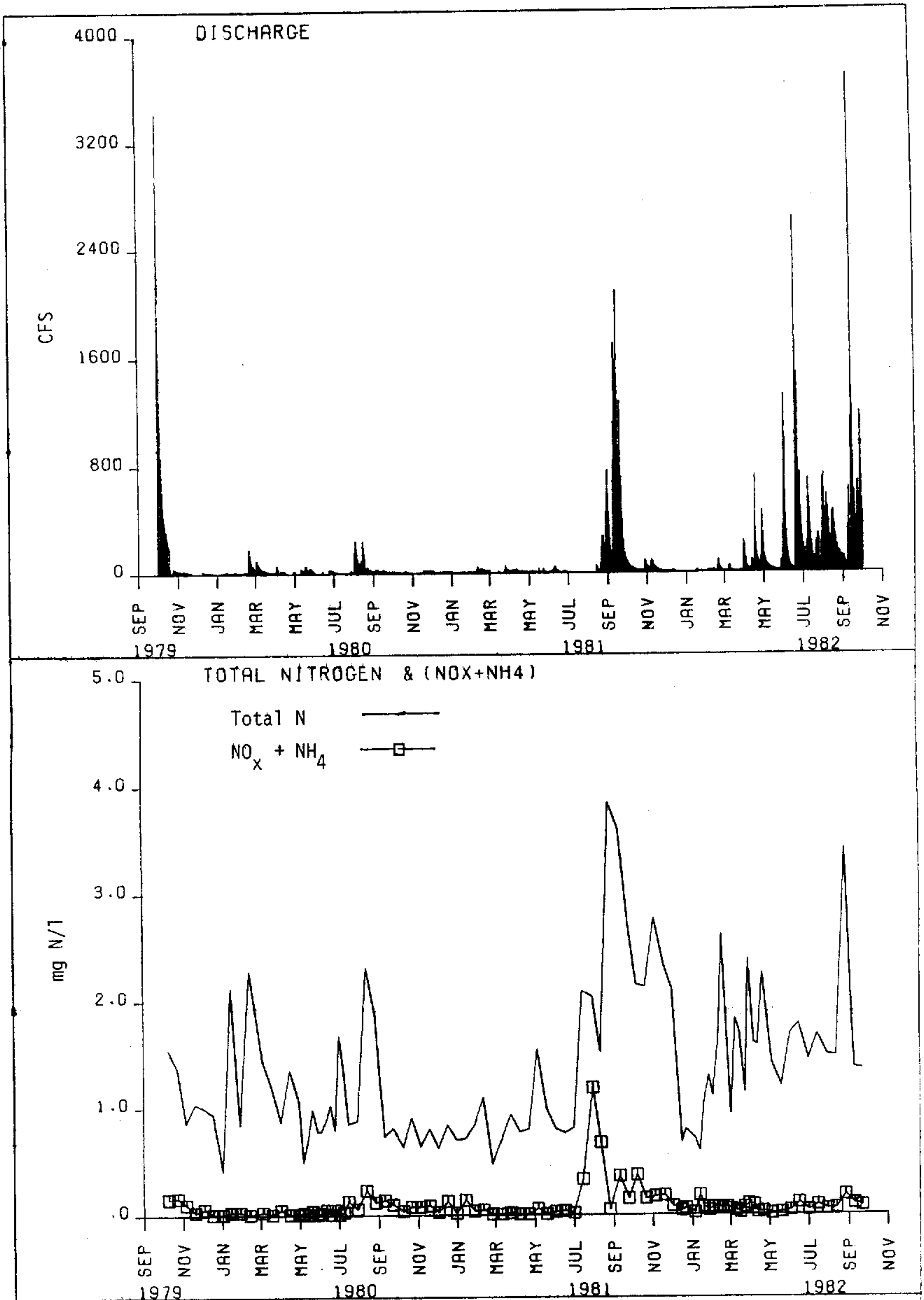


Figure 3. Time Series Concentrations Armstrong Slough-North Watershed (1979-1982) Station 2.

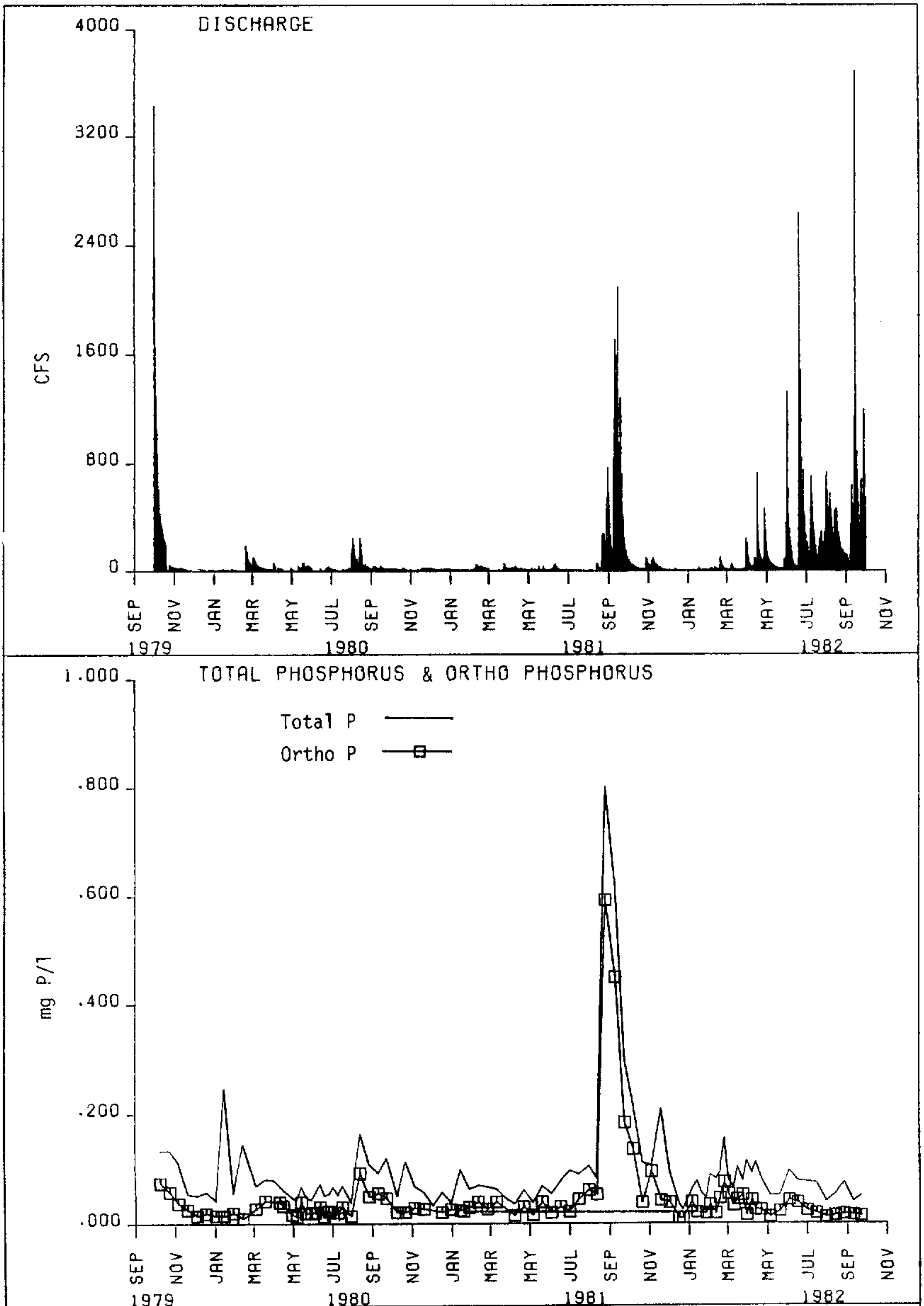


Figure V-4. Time Series Concentrations Armstrong Slough-North Watershed (1979-1982) Station 2.

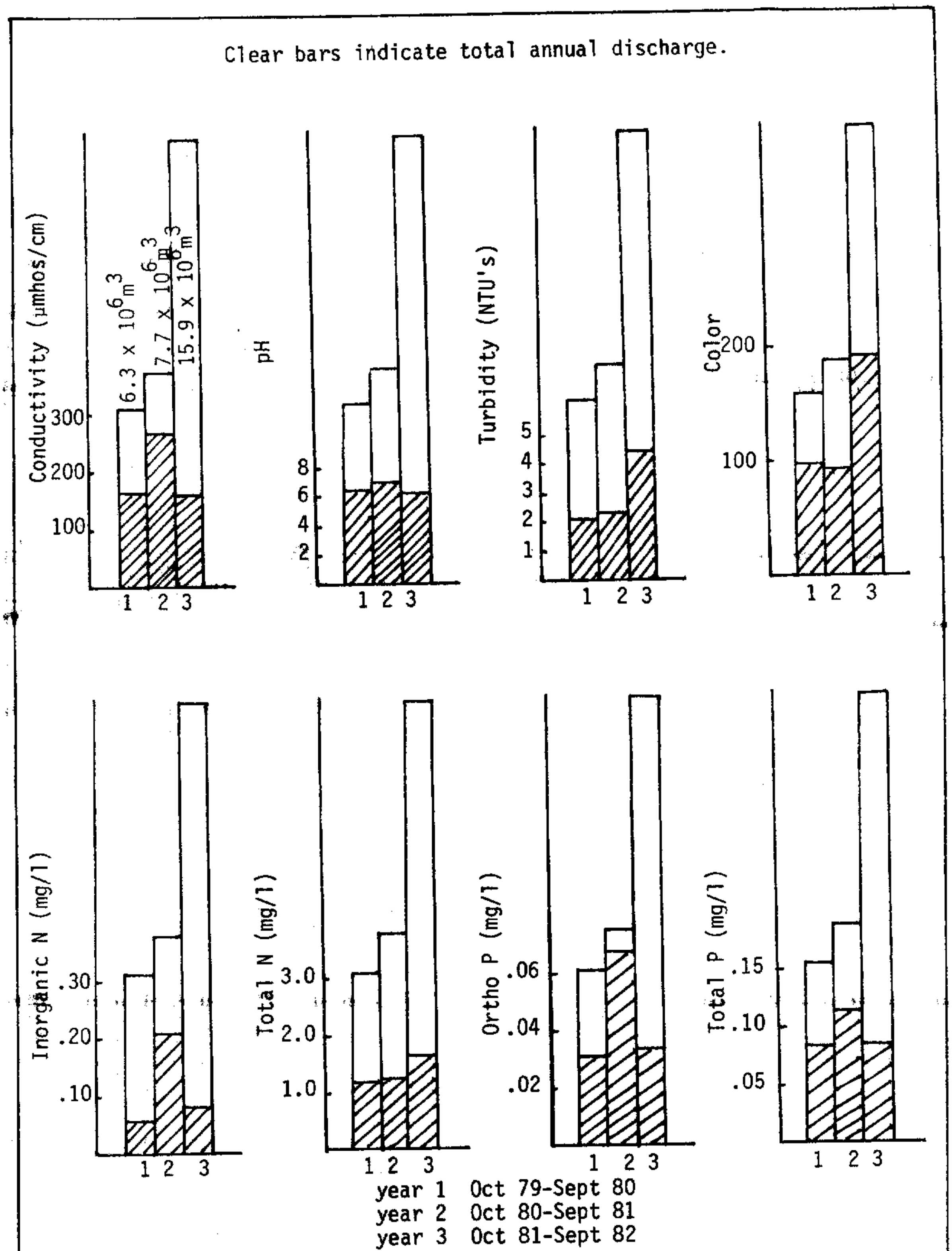


Figure V-5. ANNUAL MEAN CONCENTRATIONS AND TOTAL DISCHARGE AT ARMSTRONG SLOUGH NORTH WATERSHED

These abnormal data points tend to bias the time series average concentration for this parameter in an upward manner. If these three aberrant data points are ignored, inorganic N concentrations in runoff appear to be uninfluenced by rainfall or the lack thereof.

Total N concentrations tend to occur within the range of 0.5 to less than 4.0 ppm. Concentrations increased notably in July and August 1981 (Figure V-3) as wet season rains creating significant runoff broke the 1980-81 south Florida drought. The increase in total N concentration at this time was almost four-fold. A second increase in total N concentration occurred in February of 1982 subsequent to a severe cold snap that presumably caused the senescence, death, and decay of a good deal of vegetative matter on the watershed. Mean total N concen-trations during the wet year (1982) were about one-third higher than those noted in the two preceding dry years.

Total and ortho P concentrations for the three-year period are depicted in time series plots (Figures V-4). The most notable characteristic of these data is the existence of the "first flush" phenomenon in August of 1981 similar to that described for total N. The other notable aspect of these data is the fact that dissolved reactive (ortho) P under normal low flow or other "steady state" conditions comprises roughly about one-half of the total P, while under high flow conditions of limited duration (especially the first flush event), the ortho P component is by far the major constituent. Mean annual ortho and total P concentrations depicted in Figure V-5 seem to suggest that in years of low runoff, receiving water P concentrations are somewhat greater than in years with more extensive runoff. It should be noted that the high concentrations associated with the "first flush" event severely biased these data. Had this event not occurred, it seems unlikely that the apparent concentration/discharge relation hip would be evident.

Armstrong Slough - North Loading/Export

During the three years of study, the Armstrong Slough north watershed consistently acted as a nutrient sink for nitrogen and phosphorus.

When nutrient budgets were calculated on a monthly basis some exceptions did occur. The most notable was the apparent export of N and P in September of 1981 during the previously referenced "first flush". During that month, 9.2 percent more water was measured at the discharge monitoring station than was estimated to have fallen on the watershed as rainfall. The excess outflow volume is attributed to residual runoff of some of the rainfall temporarily stored on the watershed from the previous month. This residual runoff and associated loads that appear as a net monthly export of nutrients and flow from the watershed is largely an artifact of the calculation methods.

Even taking this into consideration, it can be argued that the watershed was less efficient in absorbing nutrients during this period than under normal circumstances, as the 9.2 percent apparent excess discharge in September 1981 was accompanied by 125.1, 502.4, and 440.4 percent more total N, ortho P, and total P, respectively, coming off the watershed than was estimated to have been added during the same period. The only other month during this study where apparent discharge/export exceeded rainfall and natural nutrient loadings on the watershed was October 1979 when similar residual flow and export occurred caused by rainfall attributed to Hurricane David which occurred during the preceding month of September. With the exception of these two months (October 1979 and September 1981) nutrient uptake (N and P) consistently occurred.

Nutrient loads on the watershed were attributed to two primary external sources, natural loads and cultural loads. Natural loads were contributions attributed to N and P dissolved in or washed out of rainfall. Cultural loads were attributed to fertilizer applications by the landowner to both improved pasture and citrus groves. Rainfall loads were estimated by methodology discussed in Section IV. Cultural loads were estimated following discussions with the landowner concerning his routine and nonroutine fertilization practices on each portion of his land. Factors taken into consideration were amount of fertilizer application, type of fertilizer application, and timing of fertilizer application. Estimated loadings were evenly spread over the months that application activities were routinely practiced. For purposes of calculation, masses of N and P in fertilizer applications were considered to be in dissolved inorganic forms and hence show up in both dissolved inorganic N and ortho P calculations as wel as those for total N and total P.

For all parameters, cultural loadings of N and P are far higher than natural loadings. Only 3 to 5 percent of the dissolved inorganic N, 7 to 11 percent of the total N, 3 to 4 percent of the ortho P, and 4 to 6 percent of the total P annual loads during the three years of study can be attributed to natural contributions.

On an annual basis, inorganic N was consistently absorbed at levels exceeding 99 percent. Total N was removed all three years at efficiencies of 95 percent or better. Uptake efficiencies did, however, decrease slightly during the third year falling to as low as 22.3 percent for a single month in September of 1981. On an annual basis, ortho P uptake exceeded 96 percent and was better that 99 percent for two of the three years. During August and September of 1981, ortho P was net exported from the watershed in excess of estimated loads. Residual loads from fertilizer applications during antecedent months and subsequent washout probably account for the major share of this loss. Total P concentrations followed the same general trends. Annual uptake exceeded 95 percent.

Phosphorus export rates (Figure V-6) were similar for the first and third year of the study. The export rate for the second year was over five times greater, almost all of the increase attributed to P export occurring in the first flush following the prolonged drought.

Export rates of total N did appear to be somewhat related to increases in discharge. The comparatively high N export rate noted in the second year of the study was largely a result of the one month first flush phenomenon in September of that year.

Annual nutrient export rates for inorganic N were calculated and averaged 0.38 kg/ha/yr over the three year study period. Average annual export rates for total N, ortho P, and total P over the three year study were 6.16, 0.32, and 0.53 kg/ha/yr, respectively.

The watershed absorbed an average of 193.7 kg/ha/yr total N and 20.8 kg/ha/yr total P during the three years. The major portion of this was culturally applied as fertilizer for citrus and/or improved pasture.

On an average annual basis only 0.2 percent of the total inorganic N applied to the watershed was released. Percent of total N, ortho P, and total P released on the same basis was 3.2, 1.2, and 2.5 respectively.

It can be concluded that rainfall contributions of nutrient loads on the watershed are comparatively small. Sufficient rainfall, properly timed, can result in increases in surface water runoff, particularly if soils are already saturated. This runoff can carry with it dissolved and particulate nutrients. This load can be comparatively large when the event follows a prolonged antecedent dry period where materials (particularly from cultural activities) are allowed to accumulate on the watershed. It can also be concluded that this watershed, given the land uses that occur on it, has the capability of absorbing quantities of N and P far in excess of those attributed to loadings derived from natural sources.

ARMSTRONG SLOUGH - SOUTH

Time Series Data

The smaller of the two distinct watersheds at the Armstrong Slough site covers approximately 2,500 acres (1,012 ha). Land use is a combination of native range (approximately 135 ha or 13 percent), cleared improved pasture (approximately 790 ha or 78 percent), and highly improved ditched pastures (approximately 92 ha or 9 percent) interspersed with some lower wetland areas.

Cattle and other livestock are grazed in this area. Stocking density is roughly one animal per 5 acres (0.2 cows/acre). Typical land management practices are similar to those utilized on the north watershed.

Ideally, fertilization of improved pasture is conducted on an annual basis. Due to costs and logistics, fertilizer application in reality averages about once every 2 to 3 years over the watershed. A different portion may be fertilized each year but not the entire watershed. Application rates are normally 300 pounds per acre of 16-4-8 or similar formulation. Application typically occurs during the months of April, May, and June.

During the three study years, this watershed experienced both extreme drought and extreme flood. During one extreme event, discharge across the flow measuring device (critical depth flume) was of such magnitude that the structural integrity was destroyed and it became necessary to reconstruct a larger device. At the other extreme, on at least two separate occasions for up to one month at a time, there was no water at all (either standing or flowing) in the channel. All flow in the conveyance channel was the direct result of surface water runoff. Flow subsequently occurred intermittently and as a direct response to a rainfall event or sequence of such events.

In general, pH was consistently slightly acidic. Mean annual pH's ranged from about 6.0 to 6.6 (Figure V-7). This parameter seemed to follow the trends described in the northern watershed in that pH was lower during periods when discharge over the flume occurred. Again, this probably reflects the generally acidic nature of the rainfall that is responsible for runoff and flow.

Conductivity (Figure V-7) is generally lower than that noted in the northern tributary. Seasonal trends appear to be a function of the timing and magnitude of rainfall and subsequent runoff events.

Year 1 October 1979 - September 1980
Year 2 October 1980 - Sepbember 1981
Year 3 October 1981 - September 1982

Clear bars indicate total annual discharge.

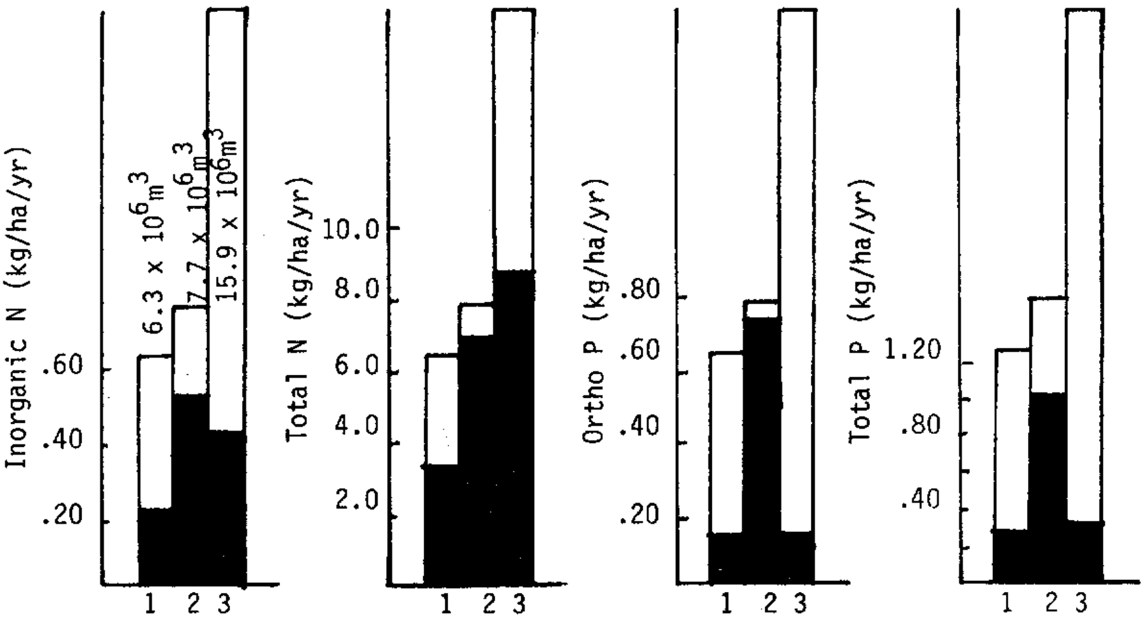


Figure V-6. Annual Mean Nitrogen and Phosphorus Export Rates from Armstrong Slough-North Watershed.

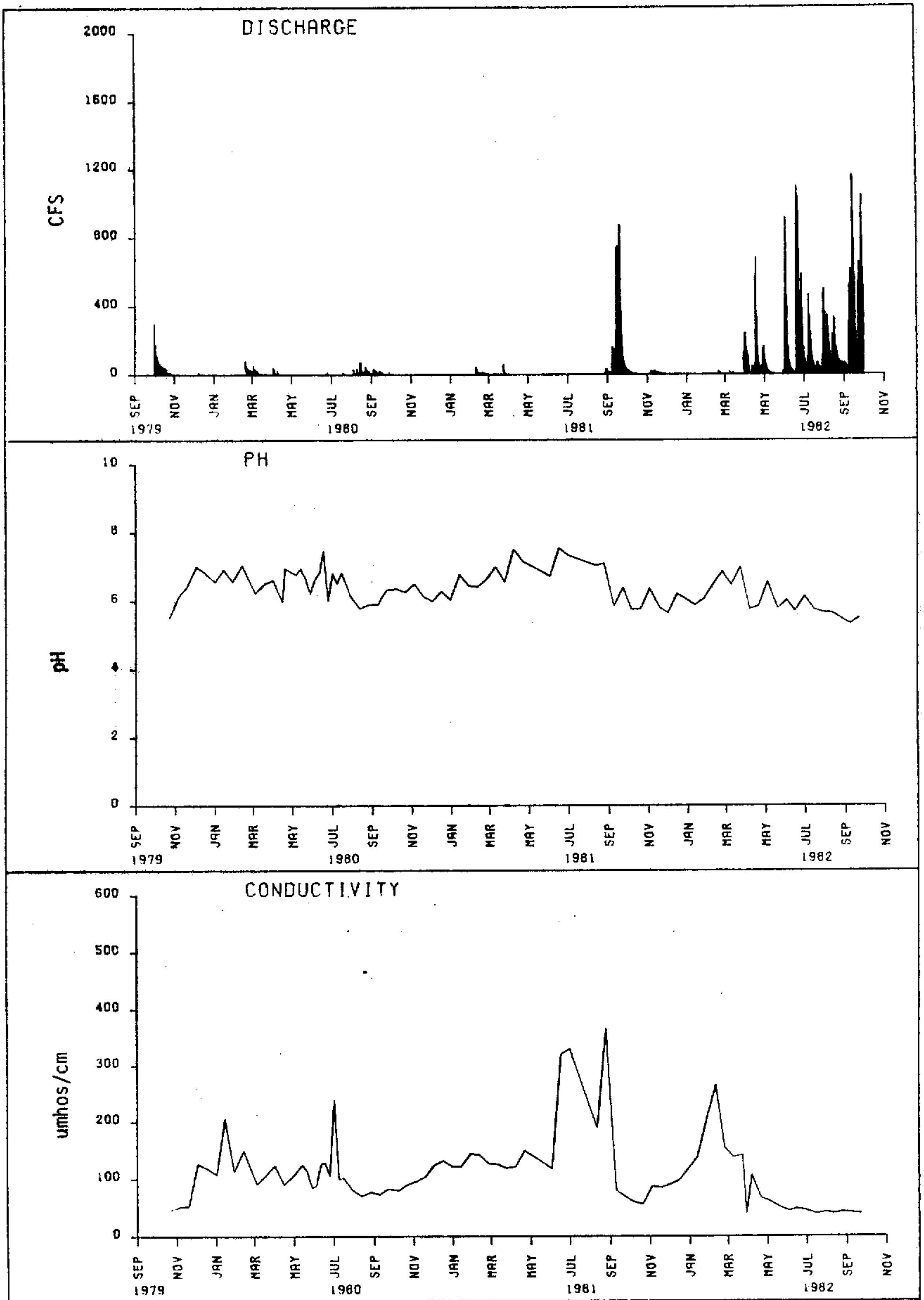


Figure V-7. Time Series Concentrations Armstrong Slough-South Watershed (1979-1982) Station 3.

Conductivity tends to drop at the onset of a significant discharge event and rise gradually following the conclusion of that event.

As a rule, turbidity levels throughout the three years of monitoring remained low (less than 3.0 NTUs) (Figure V-8). For a brief period in the spring of 1980, turbidity was significantly higher. This phenomenon is directly attributed to the flume reconstruction activities that were being conducted at the monitoring location at that time and were in no way related to normal agricultural land use activities.

Water color intensity is rather erratic during any given year (Figure V- 8); however, greater annual mean color intensities seem to correlate positively with higher annual total measured discharge.

Total and inorganic N concentrations are depicted in Figure V-9. Inorganic N concentrations are at or below detection limits. The sole exception is one aberrant data point in January 1982. Total N concentrations are relatively low (usually less than 3 ppm) with some variability. Mean annual inorganic N as well as mean annual total N concentrations seem to be relatively unimpacted by total annual discharge. Variation does appear to be lessened during periods of measurable discharge. Erratic patterns appear to be associated with those periods when no discharge occurs but water is ponded behind the flume.

Similar patterns are noted in ortho and total P concentrations (Figure V-10). The ortho P component was consistently low throughout the study. Exceptions occurred in June 1981 and February 1982. Though no discharge occurred at the flume in June 1981, enough rainfall had occurred to create standing water in the drainage ditch behind the flume. During the month prior, the ditch was completely dry. The peak in P concentrations in February 1982 can be attributed to senescence of aquatic vegetation following a hard freeze over the watershed. Annual mean concentrations of ortho and total P don't appear to be directly correlated with total annual discharge at this station (Figure V-11).

Armstrong Slough - South Loading/Export

Like its northern counterpart, runoff from the southern watershed, monitored at station 3, indicates that the subject land surface also acted as an N and P sink almost continually throughout the study.

Estimated rainfall volume on the watershed during each of the three years was in excess of 9×10^6 m^3. The distribution of rainfall over each year was variable. During the first two years of the study, the watershed was estimated to have absorbed over 80 percent of the rainfall that fell on it each year. The final year of the study turned out to be the wettest with over 14×10^6 m^3 of rain estimated to have fallen over the surface. Almost 70 percent of this estimated hydraulic load was recorded as runoff and subsequent discharge from the watershed at the monitoring station. In fact, the total hydraulic absorption on the land was calculated to be roughly half of that noted in the previous two years.

Mean annual export rates of N and P from the watershed (Figure V-12) reflected the trends in fluid absorption. Highest export rates occurred during the final year of the study when the wet season rainfall regime kept the soil continually saturated to the point where additional rainfall and associated nutrient loading became manifest as surface runoff. However, all nutrient species were assimilated by the watershed at percentages of total load equal to or in excess of percentage of water absorption, loss, or storage.

Input from cultural loads on the watershed (fertilizers) is estimated to have constituted the bulk of the nutrient inputs (66 percent or greater for total N and 88 percent or greater for total P). Mean annual uptake of the loads by the land surface substrate and vegetation was exceptionally efficient for inorganic N, ortho P, and total P (greater than 95 percent) and still quite good for total N (80 percent or greater). In all cases, the percent uptake efficiency exceeded the percent of hydraulic loss, storage, or absorption on the land surface, thus indicating that some mechanism of active uptake was operating. Since inorganic N is such a minor component of the total N load and represents species readily taken up by vegetation, it is not unexpected that uptake efficiencies are particularly good. Ortho P uptake efficiencies should also be high as that form is most easily absorbed by sediment and vegetation. Ortho P usually comprises less than half of the total P load. During September 1981, the first lush event resulted in a net export of total N, ortho P, and total P on a monthly basis. This is consistent with similar trends observed on the northern watershed and probably represents a flush of materials and water accumulated on the watershed during the previous month or months.

PEAVINE PASTURE

Time Series Data

The Peavine pasture watershed is a single 600 acre (243 ha) homogeneous land use watershed characterized as predominantly cleared, improved pasture. Grazing density on the land is approximately 0.2 cattle/acre on a year-round basis. Fertilization and

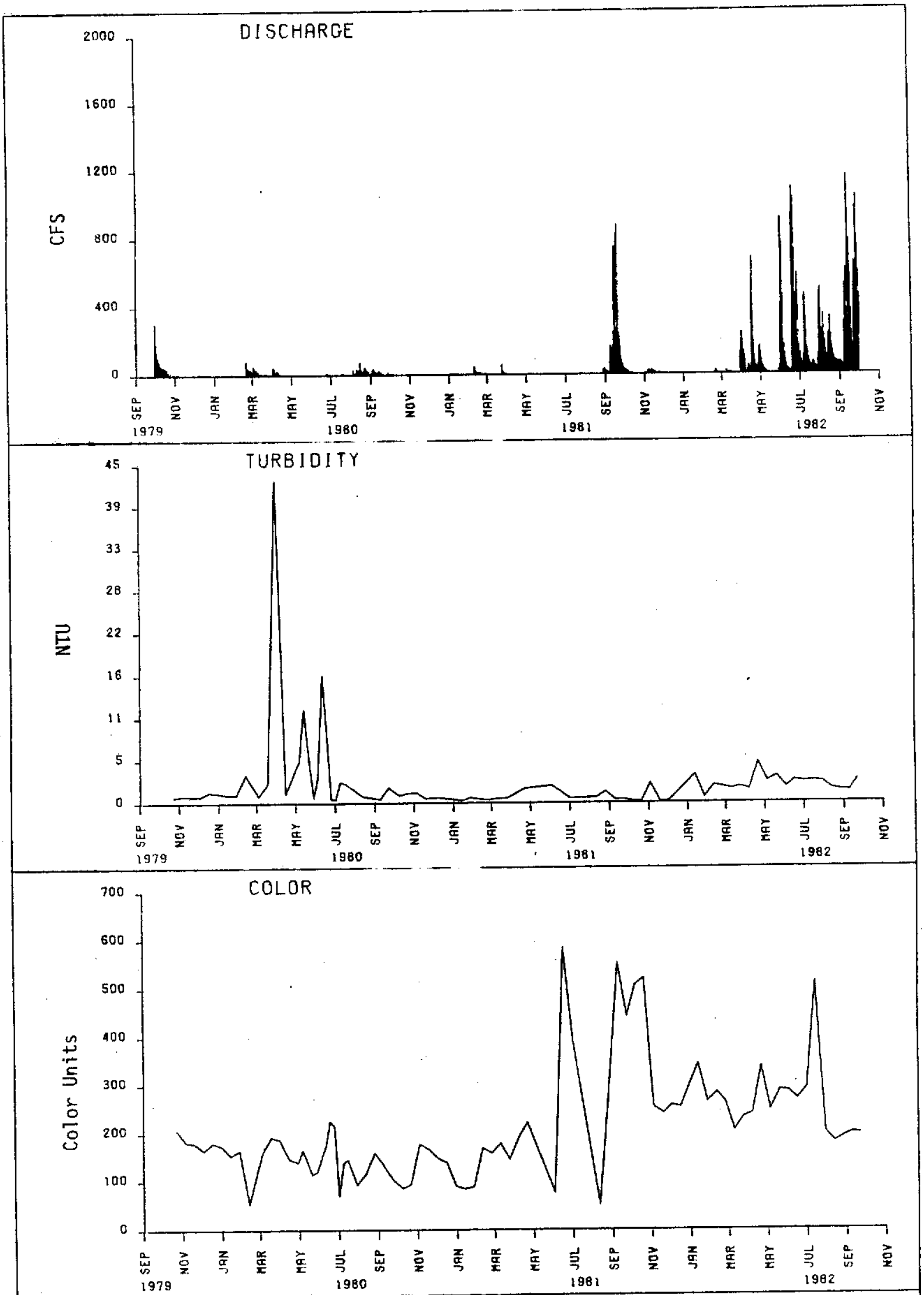


Figure V-8. Time Series Concentrations Armstrong Slough-South Watershed (1979-1982) Station 3.

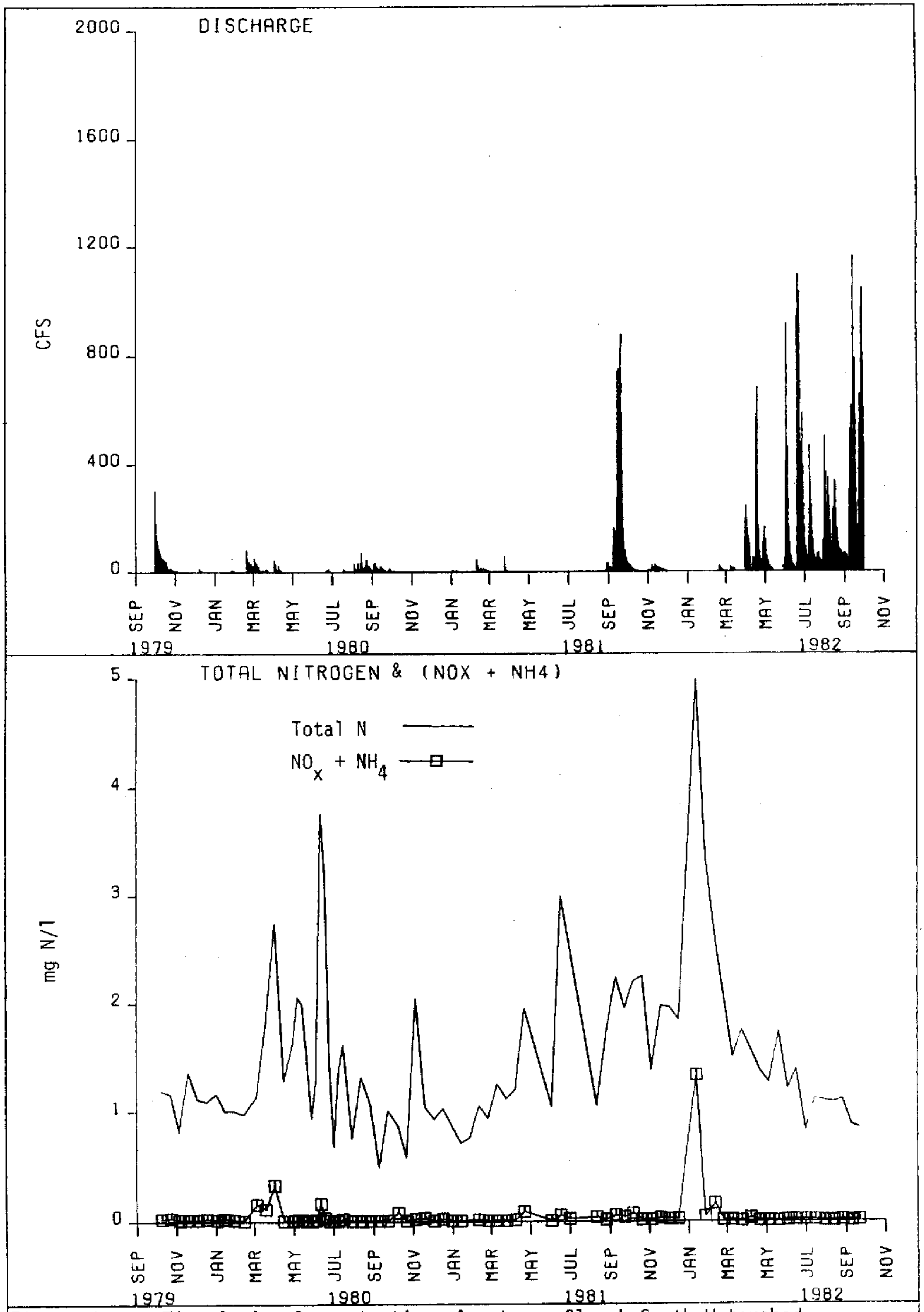


Figure V-9. Time Series Concentrations Armstrong Slough-South Watershed (1979-1982) Station 3.

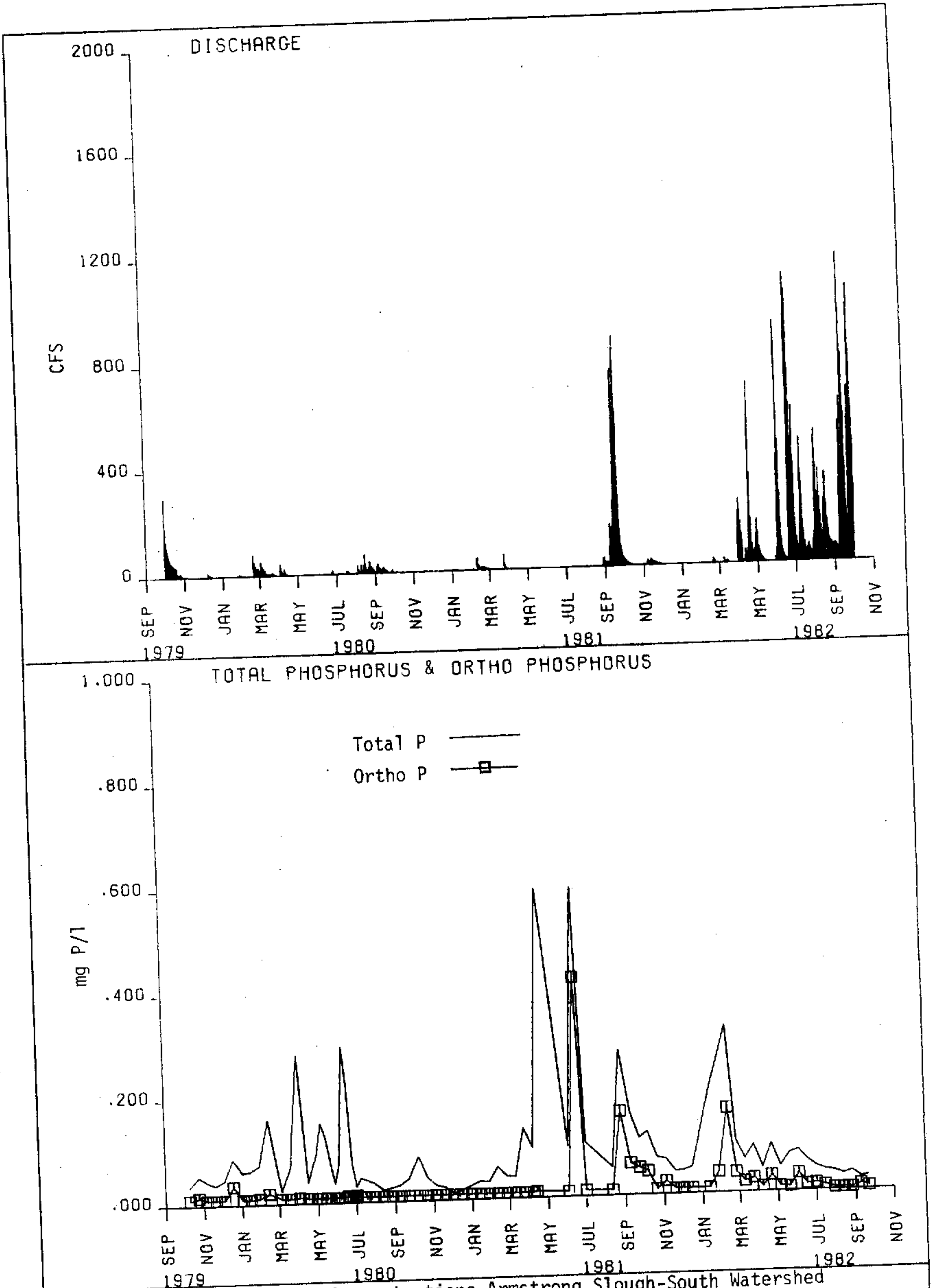
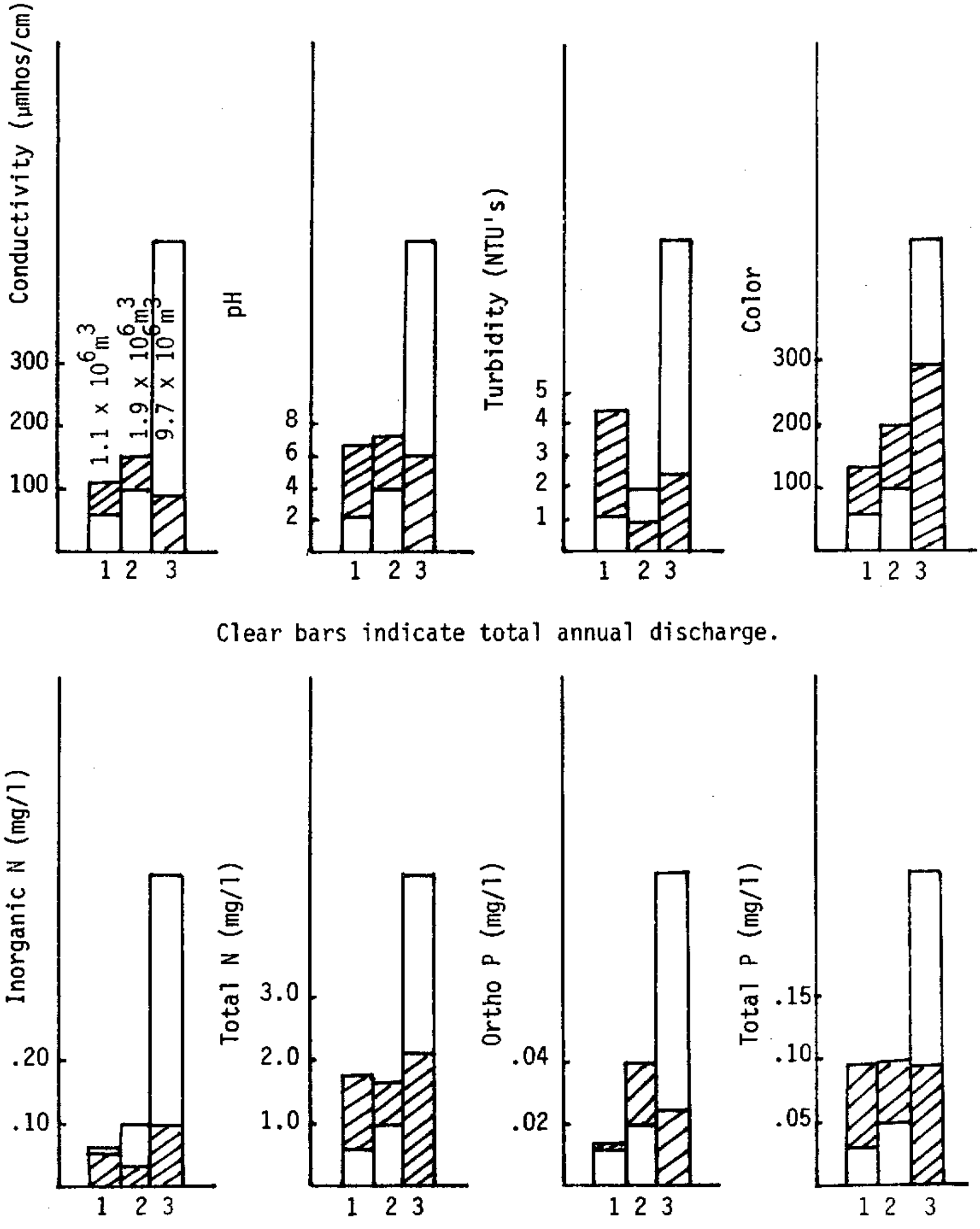


Figure V-10. Time Series Concentrations Armstrong Slough-South Watershed (1979-1982) Station 3.



year 1 Oct 79-Sept 80
year 2 Oct 80-Sept 81
year 3 Oct 81-Sept 82

Figure V-11. ANNUAL MEAN CONCENTRATIONS AND TOTAL DISCHARGE AT ARMSTRONG SLOUGH SOUTH WATERSHED

year 1 Oct 79-Sept 80
year 2 Oct 80-Sept 81
year 3 Oct 81-Sept 82

Clear bars indicate total annual discharge.

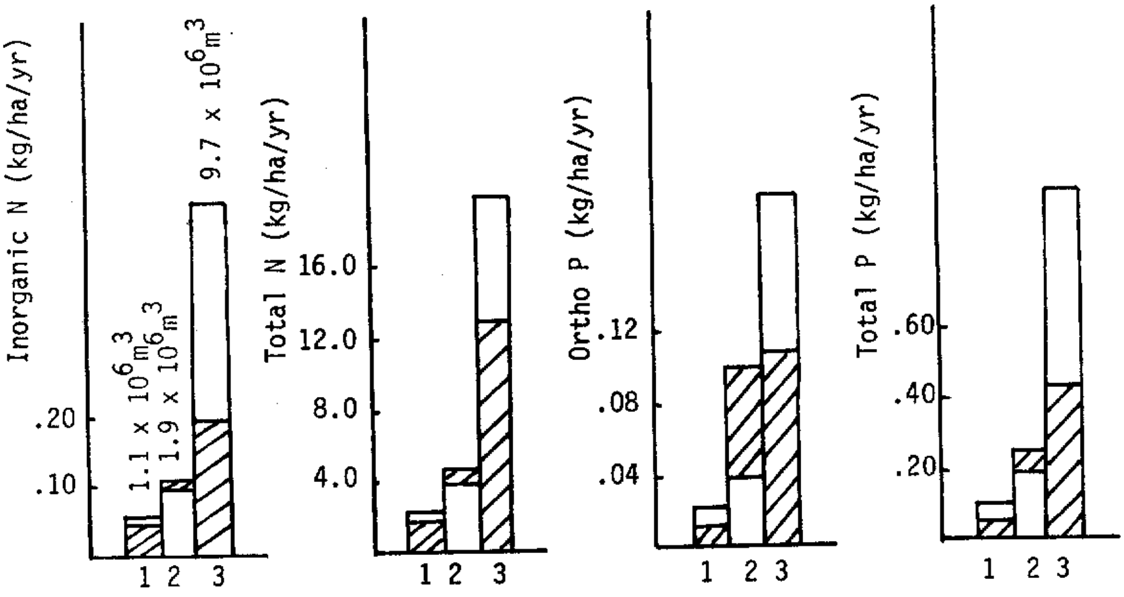


Figure V-12. ANNUAL MEAN NITROGEN AND PHOSPHORUS EXPORT RATES FROM ARMSTRONG SLOUGH - SOUTH WATERSHED other chemical application practices for pasture maintenance are typically the same as those described for similarly improved pastures at Armstrong Slough. During the three years of this study, the entire watershed was probably fertilized with the equivalent of one application of approximately 300 lbs/acre of 16-4-8 or similar formulation. The landowner (Pat Wilson, Latt Maxcy Corp.) was uncertain as to exact dates or fertilizer formulation, but indicated that this is the regimen generally followed on all of the improved pastures here at Peavine and at Armstrong Slough. For purposes of estimating nutrient load applied culturally, the total load equivalent to one application was divided by three, assuming one-third of the area was fertilized during each year For purposes of calculation, the resulting annual nutrient load was assumed to be evenly distributed over those months (April-June) that pasture fertilization is normally conducted.

Rainfall and subsequent runoff was captured in either one of the two distinct drainage ditches that converge just upstream of the concrete critical depth flume constructed at the site outfall.

Though the study began officially in October 1979, the complete 3½ year record of time series data collected at the site, plotted simultaneously with measured discharge at the flume, is depicted in Figures V-13 through V-16. Discharge volumes from the watershed were distinctively different during each of the three years of this study. During the first year, discharge events occurred as pulses regularly interspersed at 3 to 4 month intervals. During the second year, no discharge occurred until late August and September when all the measured discharge for the year occurred. The final year of study was characterized by an approximately six month long dry season with no measurable discharge followed by six months of almost continual discharge during the wet season.

The second year of the study was charact-erized by approximately twice as much discharge from the watershed as was measured during the first. This discharge occurred as a result of rainfall events in August and September. The third year was sign ficantly wetter. Discharge measured from the watershed was about seven times that of the first year. Mean annual concentrations of monitored parameters did not seem to be correlated with measured discharge totals (Figure V-17).

Time series data seem to indicate no apparent trends for either color or turbidity. With a few exceptions, color values remained around 200-250 units. Some high turbidities were noted in the fall of 1980, but these occurred in standing water behind the flume and could be indicative of animal activity (livestock lounging, etc.) and are also probably associated with an algae bloom that was noted during the same period. With this sole exception, turbidity levels were quite low.

During periods of recorded discharge, conductivity levels were low. Higher peaks were noted at least once each year but were of little importance as they occurred only in stagnant waters ponded behind the flume. Slightly acidic and stable pH values were the rule each year. No seasonal or other trends were apparent.

Nitrogen concentrations generally ranged from 1 to 3 ppm . Dissolved inorganic N was almost always at or below detection limits. The main exception to these trends occurred in the latter part of 1980 when total N concentrations suddenly increased to the range of 10-15 ppm. Measurable amounts of dissolved inorganic N were present, but for the most part, represented only a small fraction of the total N present. Following this sudden increase, nitrogen concentrations gradually decreased and leveled off at concentrations only slightly greater than those that were the rule prior to the previous October. Only near the end of the final year of this study (July-September 1982) did total N concentrations finally decrease to pre-October 1980 levels.

Total P concentrations followed similar general trends and, in addition, appeared to decrease slightly during periods of measurable discharge at the monitoring station. Total P concentrations were generally much less than 0.100 ppm during the first and last year of the study. Like total N, concentrations increased dramatically to over 1.2 ppm in October of 1980, then gradually declined to about 0 10 ppm where they remained until the end of the study.

Ortho P was usually the minor constituent of the total P component. During the period October 1980 through January 1982, however, it appeared to comprise one-third to one half of the total P concentration

. The sudden and dramatic increases in total N and P concentrations as well as turbidity that occurred in October of 1980 cannot be readily explained by any one particular land use practice or event. According to the landowner, pasture fertilization would have been conducted in the months of April, May, or June, thus it is unlikely that this was a primary cause. The predominance of the N and P in particulate form also tends to rule this out. More likely, a combination of factors were responsible: These included the gradual reduction of standing water in the ditch through evapotranspiration and the increased utilization of

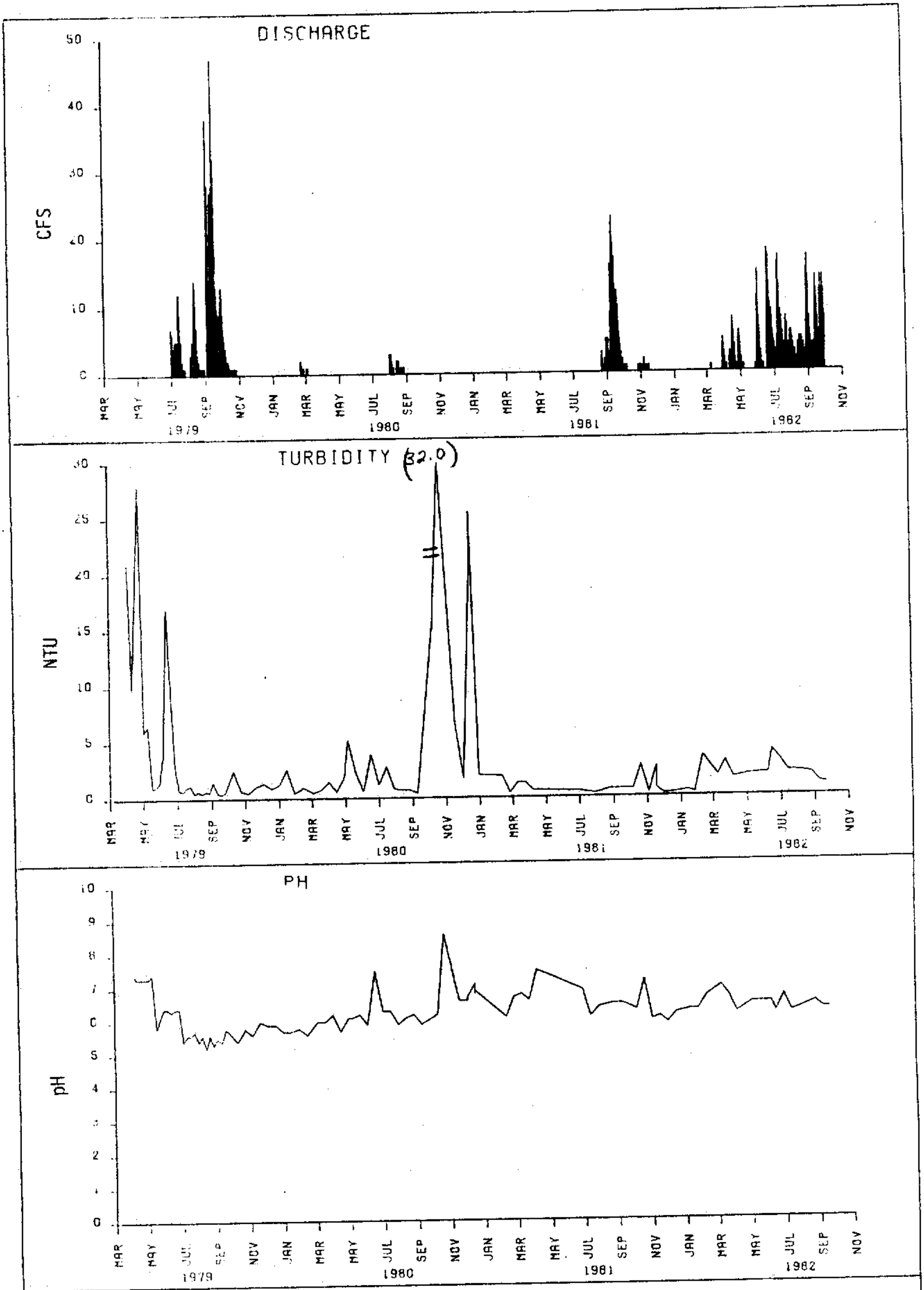


Figure-V-13. Time Series Concentrations Peavine Pasture (1979-1982).

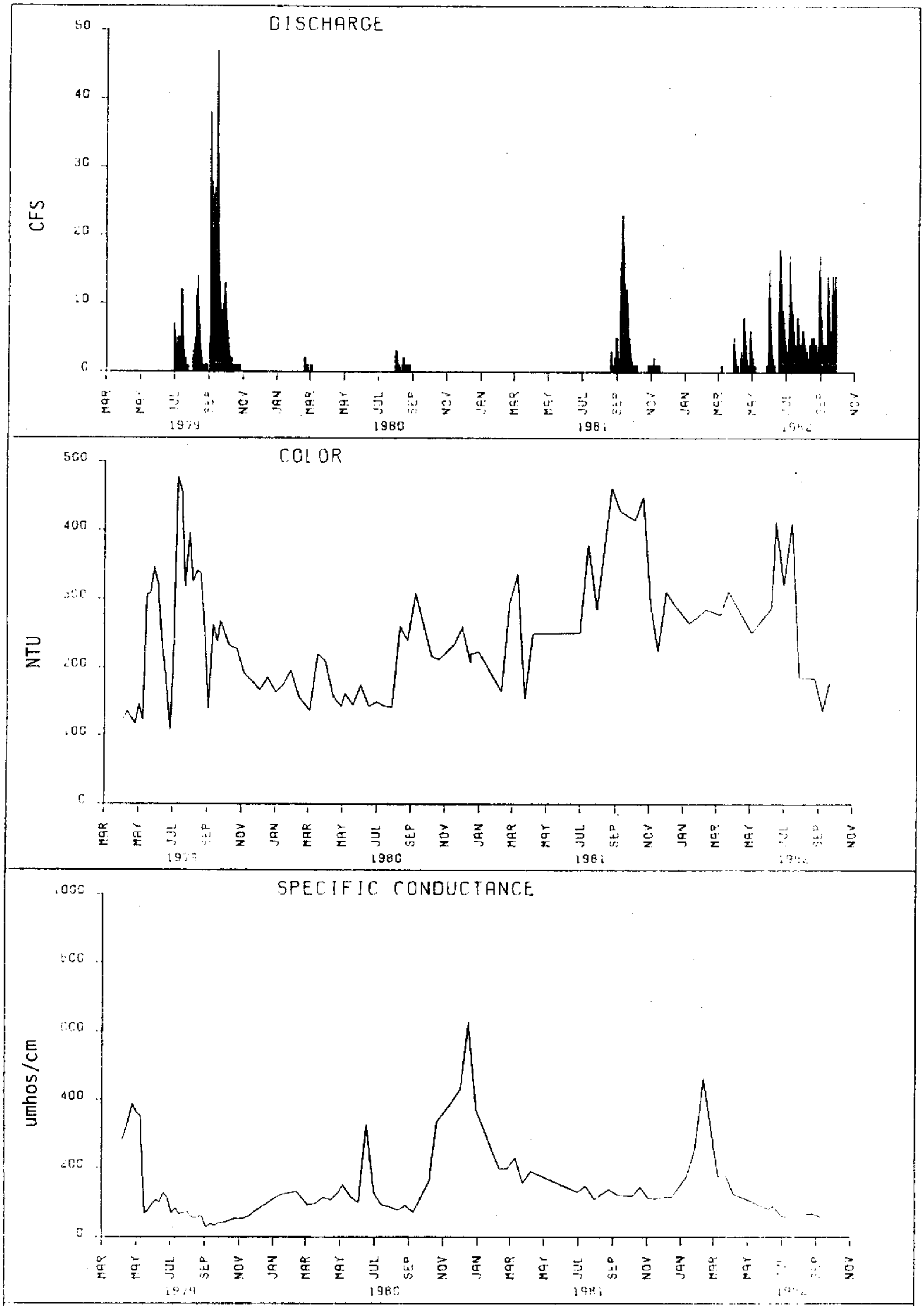


Figure V-14. Time Series Concentrations Peavine Pasture (1979-1982).

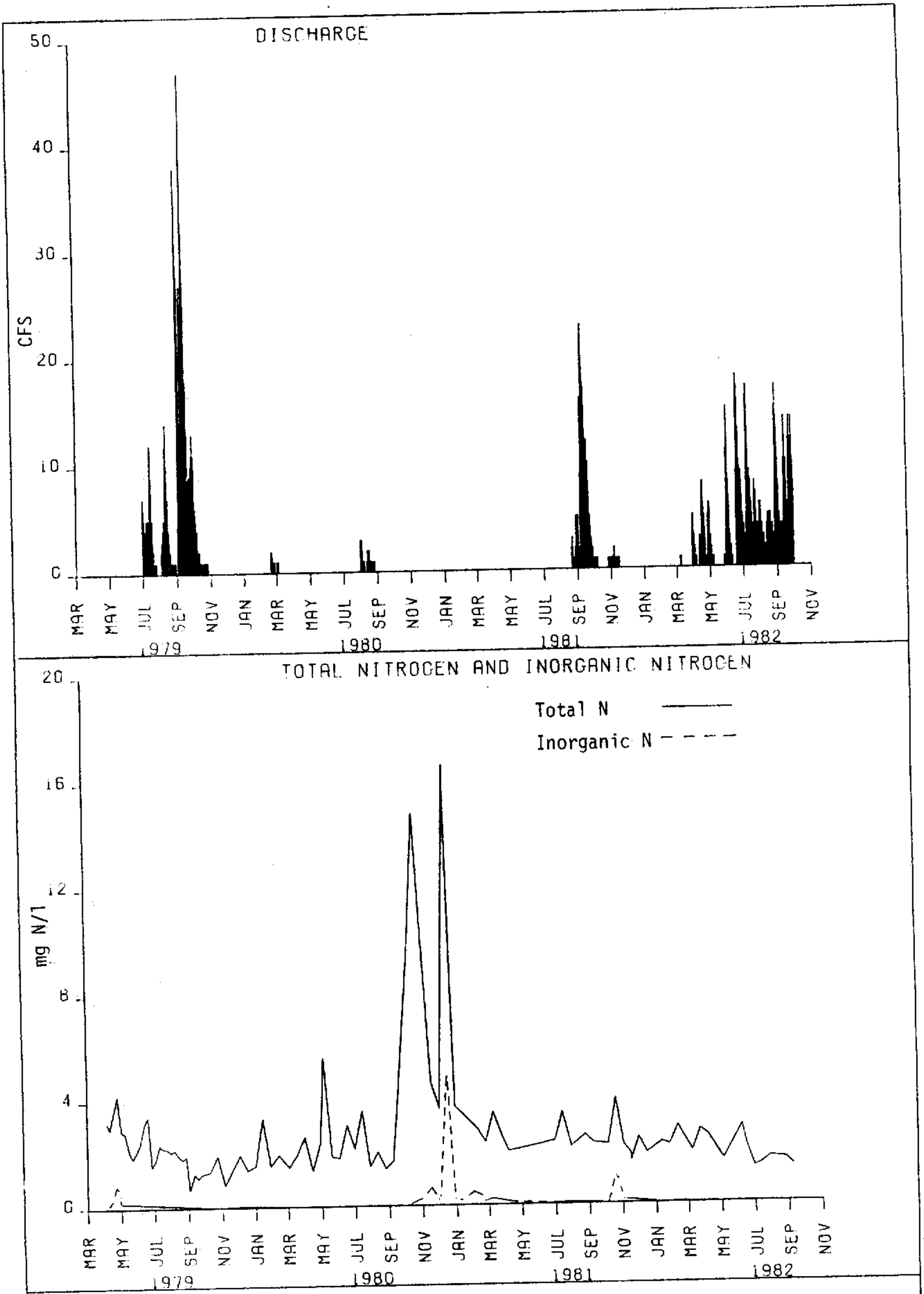


Figure V-15. Time Series Concentrations Peavine Pasture (1979-1982).

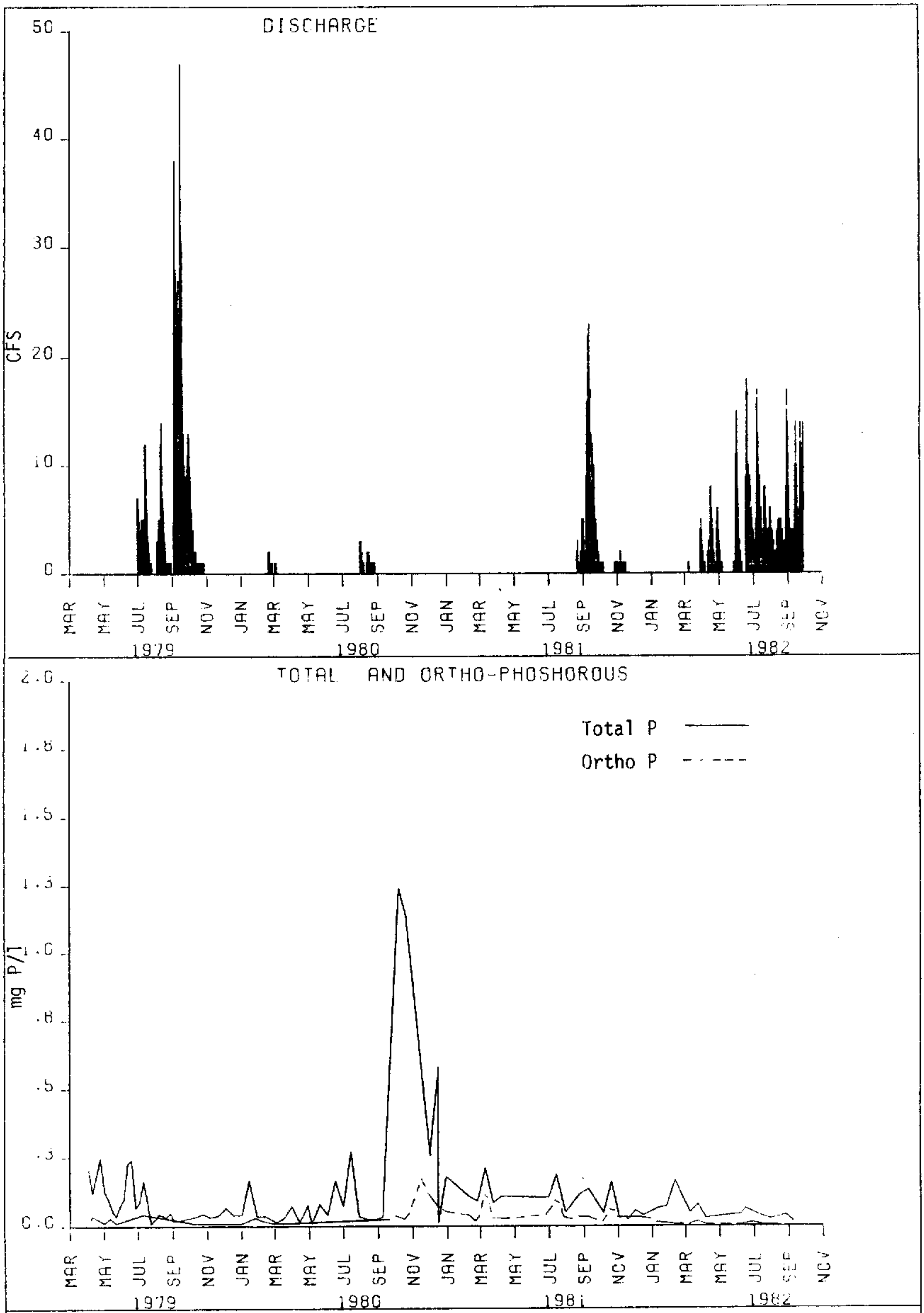


Figure V-16. Time Series Concentrations Peavine Pasture (1979-1982).

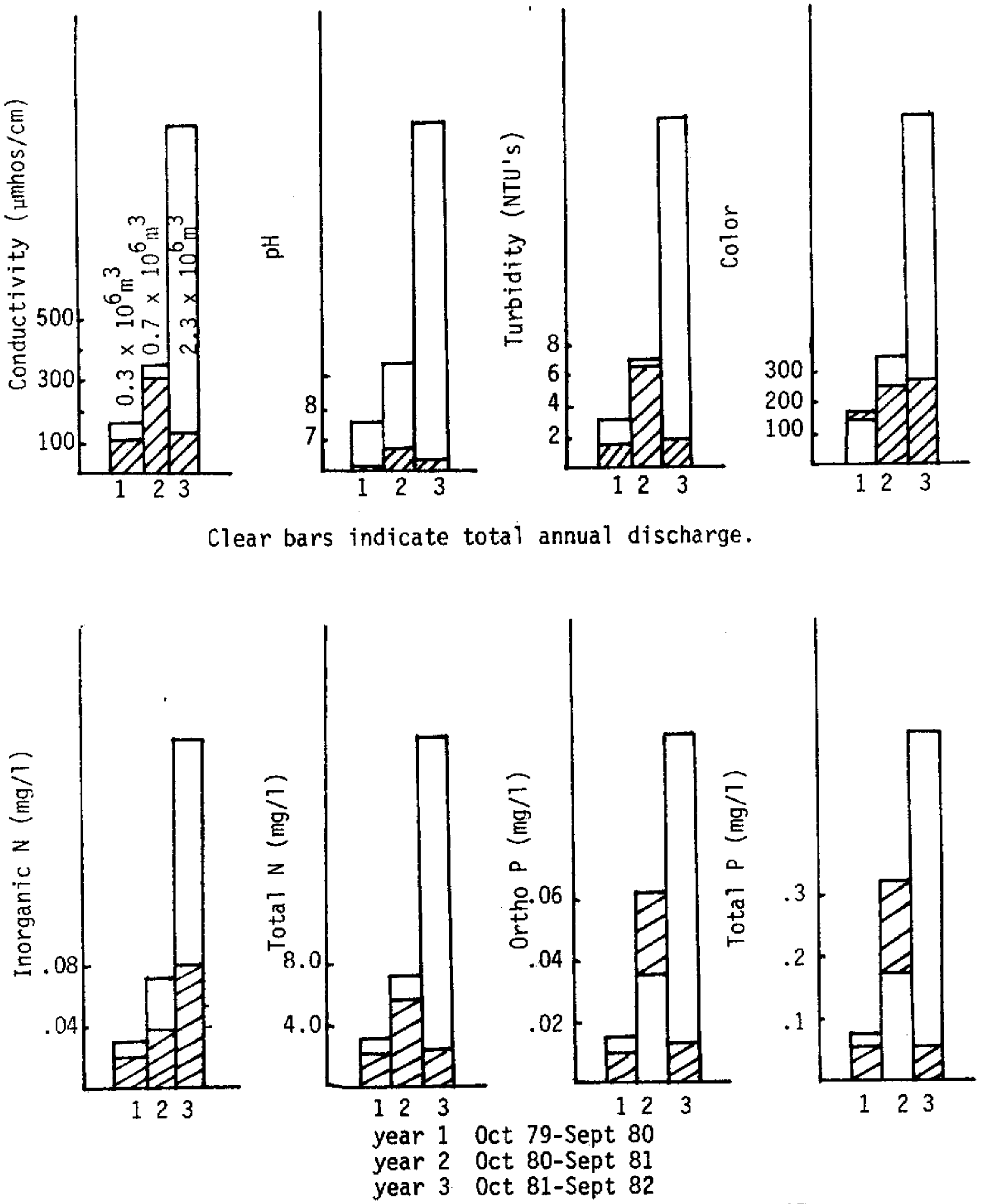


Figure V-17. ANNUAL MEAN CONCENTRATIONS AND TOTAL DISCHARGE AT PEAVINE PASTURE this area by cattle attracted to the standing water during this rather dry period. Field notes for October 1980 indicate that a significant algal bloom occurred at the sampling station during this time. This would account for the predominance of N and P in the particulate state with concurrently low dissolved inorganic N and ortho P constituents being absorbed from the water column.

Peavine Pasture Loading/Export

As one might expect, water storage in the soils occurs throughout the drier portions of the year as rainfall is readily absorbed. Once the watershed soil is saturated, additional rainfall is transformed into surface water runoff. This runoff is augmented by subsurface drainage of previously absorbed water. The resulting flow past the monitoring station can, under these conditions on a monthly basis, exceed the estimated rainfall volume. This was the case in October 1979, as well as during September 1981, and June through September of 1982.

Distribution of the rainfall events appears to be most important. During the first two years of this study, the total annual rainfalls were similar, 1.4×10^6 m^3 versus 1.7×10^6 m^3. Almost 80 percent of this rainfall, however, was absorbed on the watershed the first year as opposed to approximately 60 percent during the second. In the second year, the bulk of the rainfall occurred in July, August, and September and resulted in totally saturated soils over most of this continuous period of time. Thus more runoff and less uptake occurred.

On an annual basis, N and P loads were absorbed by the watershed during each year; however, total N was exported during several months. On only two occasions (October 1979 and September 1981) was total P exported. Net uptake of inorganic N and ortho P was noted for each month except October 1979 (following Hurricane David).

On an annual basis, water retention on the watershed was 78.1, 59.5, and 20.9 percent, respectively, for each year of the study. Pasture maintenance practices (fertilization) were estimated to have contributed roughly 92 percent of total N loading on the watershed during the study. Annual percent total N retention on the watershed was inversely related to the total measured discharge from the watershed. Percent uptake ranged from 82.2 in the final year of the study to 98 percent during the first year. Export rates in kg/ha increased as discharge volume increased (Figure V-18). Estimated nitrogen absorption on the watershed ranged from 73 kg/ha/yr to almost 94 kg/ha/yr. The dissolved inorganic N loads contributed by rainfall were small. Cultural loading was considered to be in this inorganic form since dissolution of the chemical pellets was assumed to be necessary before it became available for plant uptake. Total N uptake then was largely a measure of inorganic N uptake of applied fertilizers. The annual percentage uptake in the N budget was greater than the annual percentage of water loss in the water budget; therefore, it can be concluded that nitrogen is being actively assimilated on this watershed.

Percent ortho and total P uptake was also in excess of that which could be expected by passive water loss or storage alone. Like N, the major portion of the annual load (about 96 percent) was considered to be contributed in the dissolved reactive form from dissolution of fertilizer pellets. Uptake on the watershed was consistently slightly greater than 22 kg/ha/yr. That is, almost all that was applied was absorbed (98.5 percent or better annually). Only during the "first flush" event of September 1981 did quantities estimated to be leaving the watershed exceed those contributed for the month. This is an artifact of the hydraulic regime as residual water stored on the watershed during the previous wet month was discharged. Export rates of P from the watershed ranged from about .04 to .34 kg/ha/yr but did not appear to be directly related to total annual discharges. Instead, lowest export rates occurred during the first year of study when rainfall distribution was spread out so that runoff and dischar e were minimized.

WILDCAT SLOUGH

Three distinct watersheds were monitored at the Wildcat Slough site. One of the three watersheds was a 1,730 ha area of predominantly native range interspersed with wetlands and oak and palmetto hammock. A single channel originating in a large wetland area adjacent to a dense oak/palmetto hammock provides the major avenue for drainage to occur. This watershed, located on the western portion of the site, was appropriately designated as Wildcat Slough-west. The second watershed, located on the northeastern portion of the Wildcat Slough site, is drained by a distinct channel originating in a large wetland area (Pitman's bay) and winding southward. This tributary drains an estimated 2,590 ha watershed of largely native range interspersed with some cleared pasture with only slight to moderate improvements. This watershed was labeled as Wildcat Slough-east.

The confluence of these two channels occurs one-half mile (0.9 km) upstream of the Wildcat Slough outfall and nearly one-quarter mile (0.4 km) downstream

year 1 Oct 79-Sept 80
year 2 Oct 80-Sept 81
year 3 Oct 81-Sept 82

Clear bars indicate total annual discharge.

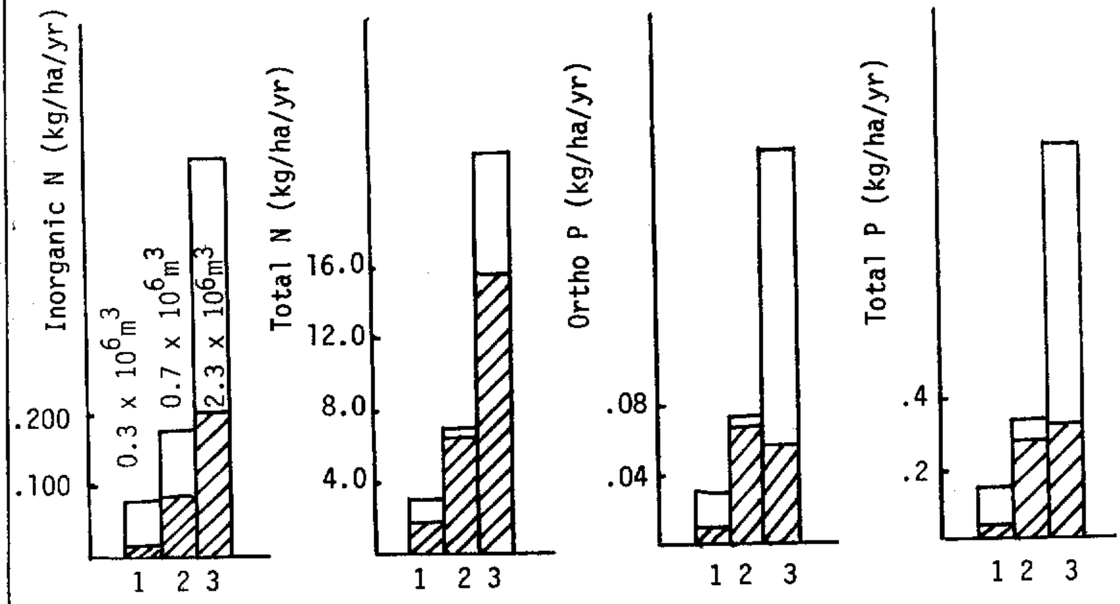


Figure V-18. ANNUAL MEAN NITROGEN AND PHOSPHORUS EXPORT RATES FROM PEAVINE PASTURE of the Wildcat Slough-west monitoring station. The area downstream from the two upper watershed monitoring stations which contribute runoff and drainage to the channels and ultimately into canal C-41A is roughly 2,107 ha. This was considered to be the third watershed. This land is largely native range with some cleared, slightly improved pasture and some ponded wetlands.

Livestock grazing density throughout all of these areas was approximately 0.05 cattle per acre. Pasture maintenance practices were nonexistent or minimal (no supplemental fertilizers, etc.). Land use at this site is less influenced by cultural practices than that which is characteristic at any of the other Upland Demonstration Project sites and is thus more representative of natural conditions.

WILDCAT SLOUGH - EAST

Time Series Data:

Color and turbidity levels (Figure V-19) are comparatively low and relatively constant. Color ranges from 49 to 529 units but the differences do not appear to be correlated with either season or discharge volumes. There is a trend toward higher concentrations over time with mean annual color levels for the final year of the study approximately twice those noted during the first year. Mean annual turbidity levels are low. When peaks occur, they are always attributable to livestock activity around the monitoring station - particularly during the drought.

Mean annual pH levels (Figure V-20) were slightly acidic ranging from 5.6 to 6.84. As a rule, pH tended to become lower during periods of discharge, presumably reflecting the slightly acidic nature of rain generated runoff.

Conductivity (Figure V-20) was highest during the drought year (1980-81). Mean annual concentrations were about 2.5 times greater during that period than in either of the other two years. Conductivity levels remained below 500 µmhos and commonly at 100 µmhos or less.

With only rare exceptions, inorganic N concentrations were at or below detection limits (Figure V-21). Sole exceptions occurred in June of 1980, December 1980, and May of 1982. Total N followed similar patterns. The dissolved inorganic portion was only a small percentage of the total N. Total N concentrations appeared to be lowest during periods of observed measurable discharge but no clear distinct patterns are evident.

Ortho P concentrations (Figure V-22) were at or below detection limits for most of the study. Total P concentrations were lowest during periods of measurable discharge. In general, P concentrations here were among the lowest noted at any of the Upland Demonstration Project sites. (Figure V-23).

Wildcat Slough - East Loading/Export

During the three years of study, this watershed appeared to function as an effective sink for N and P species. This is not surprising given the fact that loads were strictly of aeolian origin. Estimated percentage of annual rainfall volume that was absorbed or stored on the land surface ranged from about 87 to 94 percent. Estimated inorganic N uptake was always in excess of 99 percent. Total N uptake ranged from 85 to 92.5 percent. Ortho P uptake was 97 to greater than 99 percent, and total P uptake ranged from 96 to 98 percent. The percent uptake of estimated natural loads coupled with the absence of application of cultural loads is reflected in the low unit area/export coefficients calculated for this watershed (Figure V-24).

WILDCAT SLOUGH - WEST

Time Series Data:

During the subject study period, only four distinct periods of significant amounts of discharge from this watershed occurred. Two of these were during the 1979 wet season, one in May and one in September. The latter was the larger of the two events and was a direct result of rainfall associated with Hurricane David. While some daily discharge was noted throughout 1980, it was in comparatively insignificant amounts. The channel was completely dry from October 1980 through late July 1981, and again from November 1981 through April 1982. A period of discharge occurred in late August through October 1982. A final continuous discharge event, the longest and largest of the four, began in June of 1982 and was still in progress at the cessation of the monitoring phase of the program in early October.

Standing water behind the discharge monitoring culverts was often higher in suspended sediment material than at the other sites. This was probably due to the fact that cattle tended to utilize the pool and channel for drinking and lounging. When water was present in the channel, turbidity (Figure V-25) was higher here during the drought. Turbidity levels decreased noticeably during each of the four periods when discharge was noted. pH was generally acidic, ranging from about 5 to 6. Lower pH values occurred

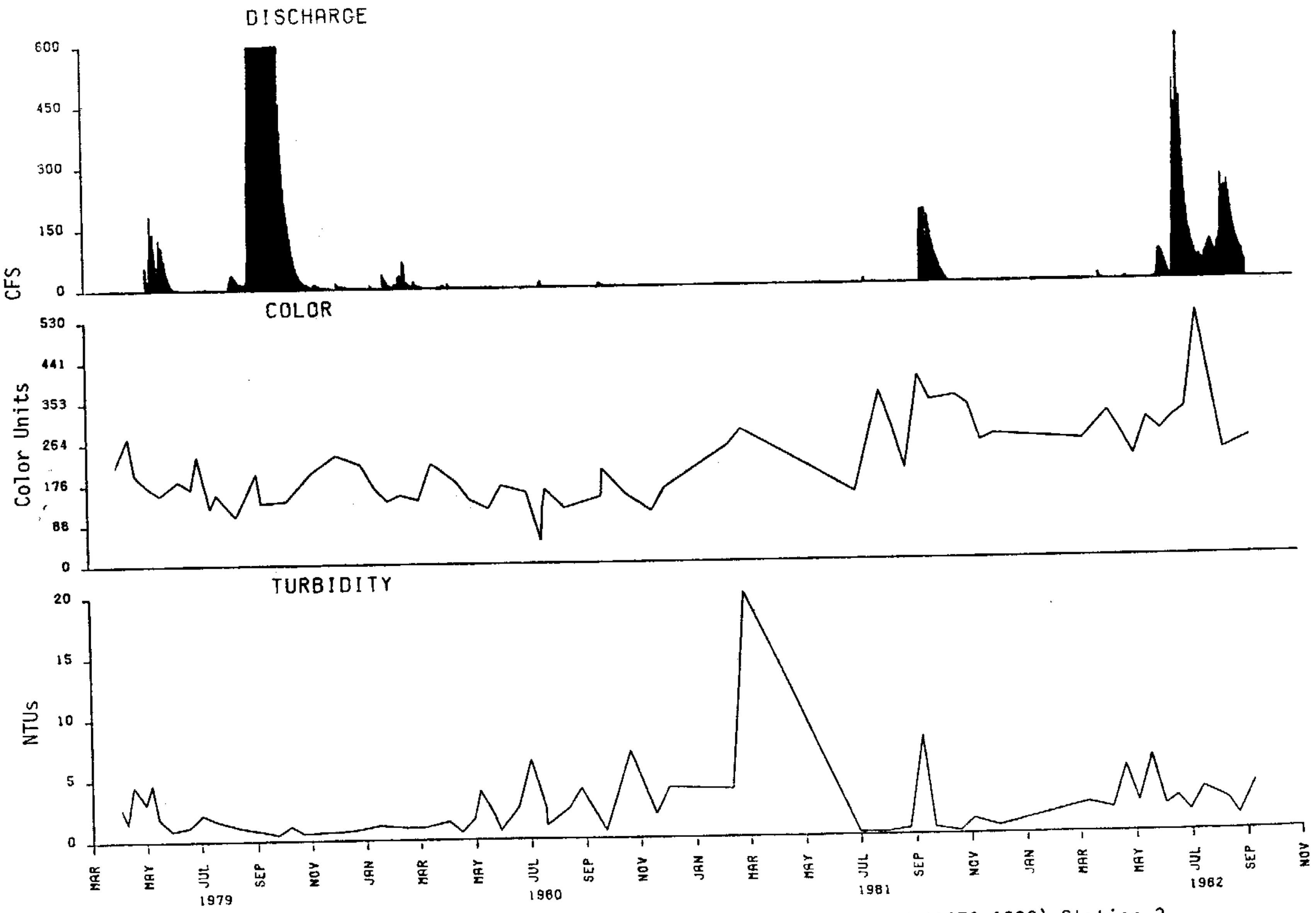


Figure V-19. Time Series Concentrations Wildcat Slough-East Watershed (1979-1982) Station 3.

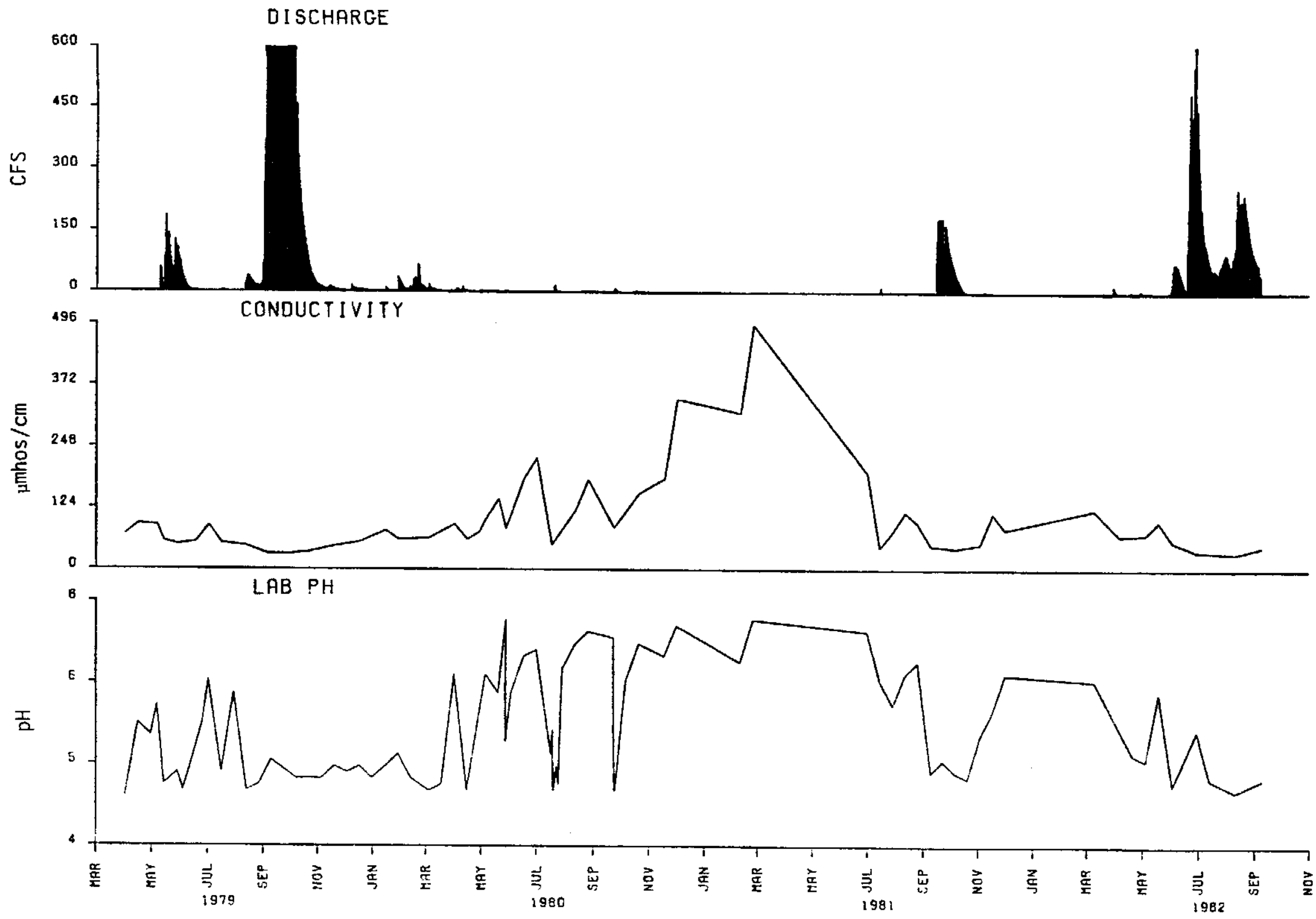


Figure V-20. Time Series Concentrations Wildcat Slough-East Watershed (1979-1982) Station 3.

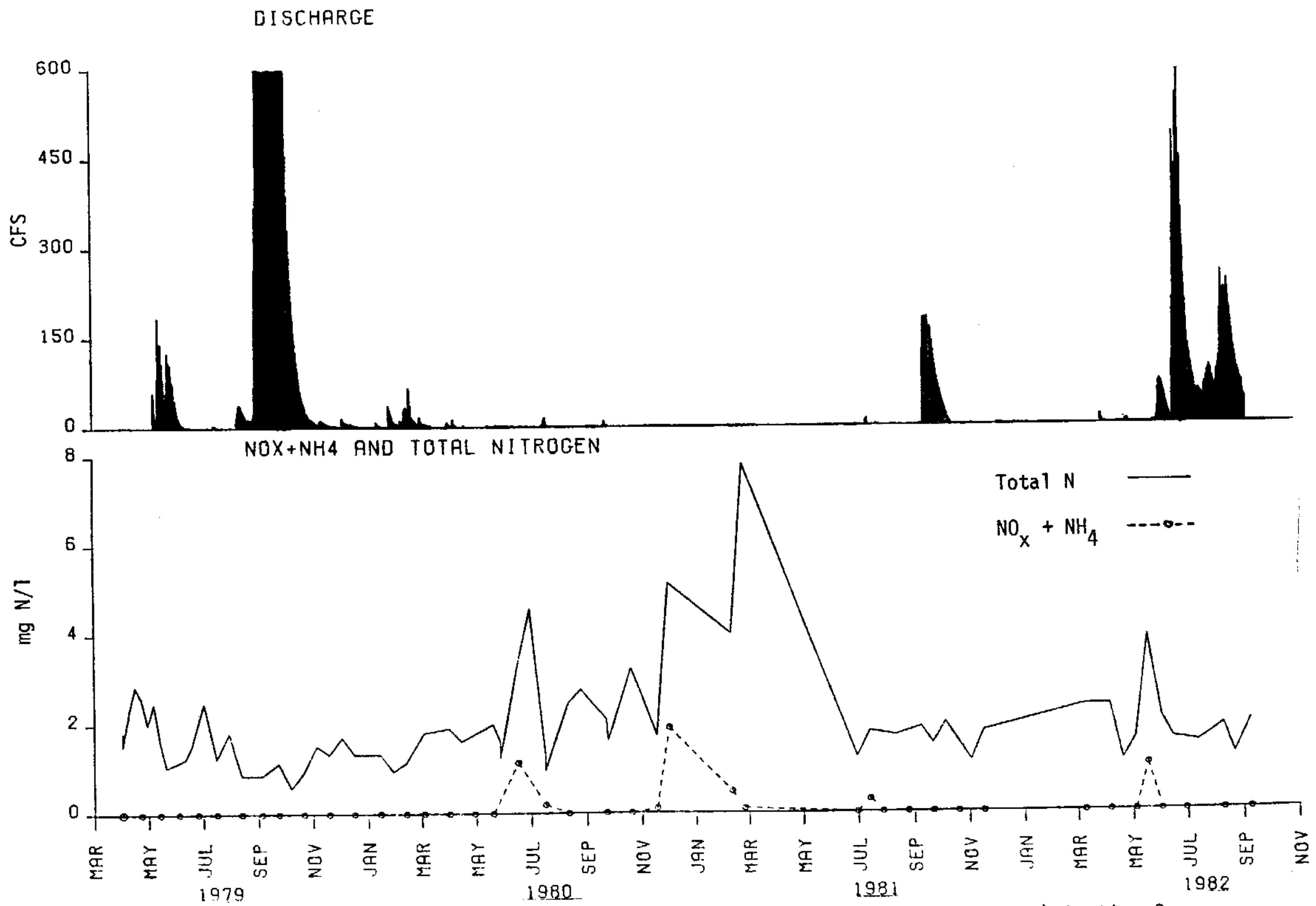


Figure V-21. Time Series Concentrations Wildcat Slough-East Watershed (1979-1982) Station 3.

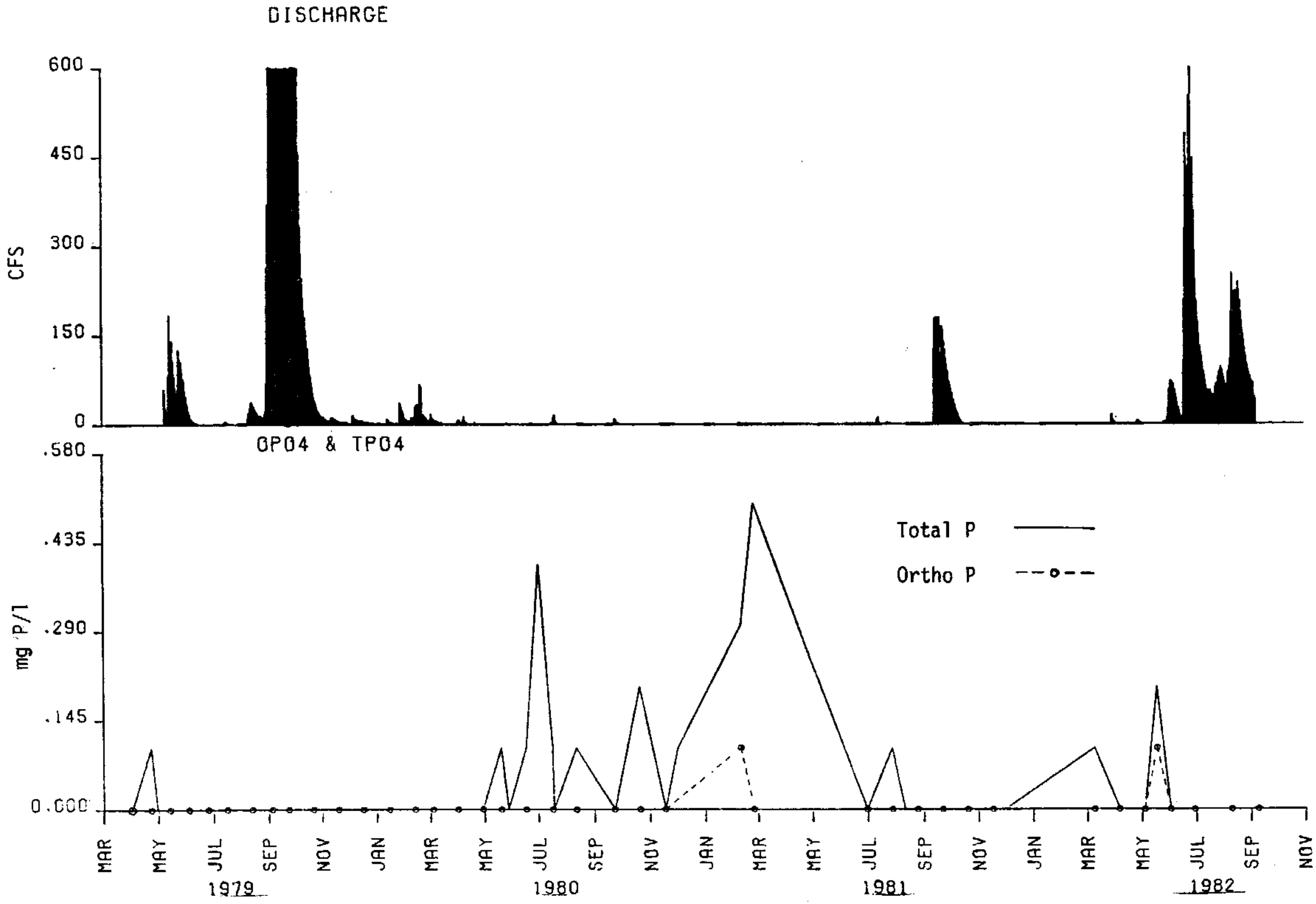


Figure V-22. Time Series Concentrations Wildcat Slough-East Watershed (1979-1982) Station 3.

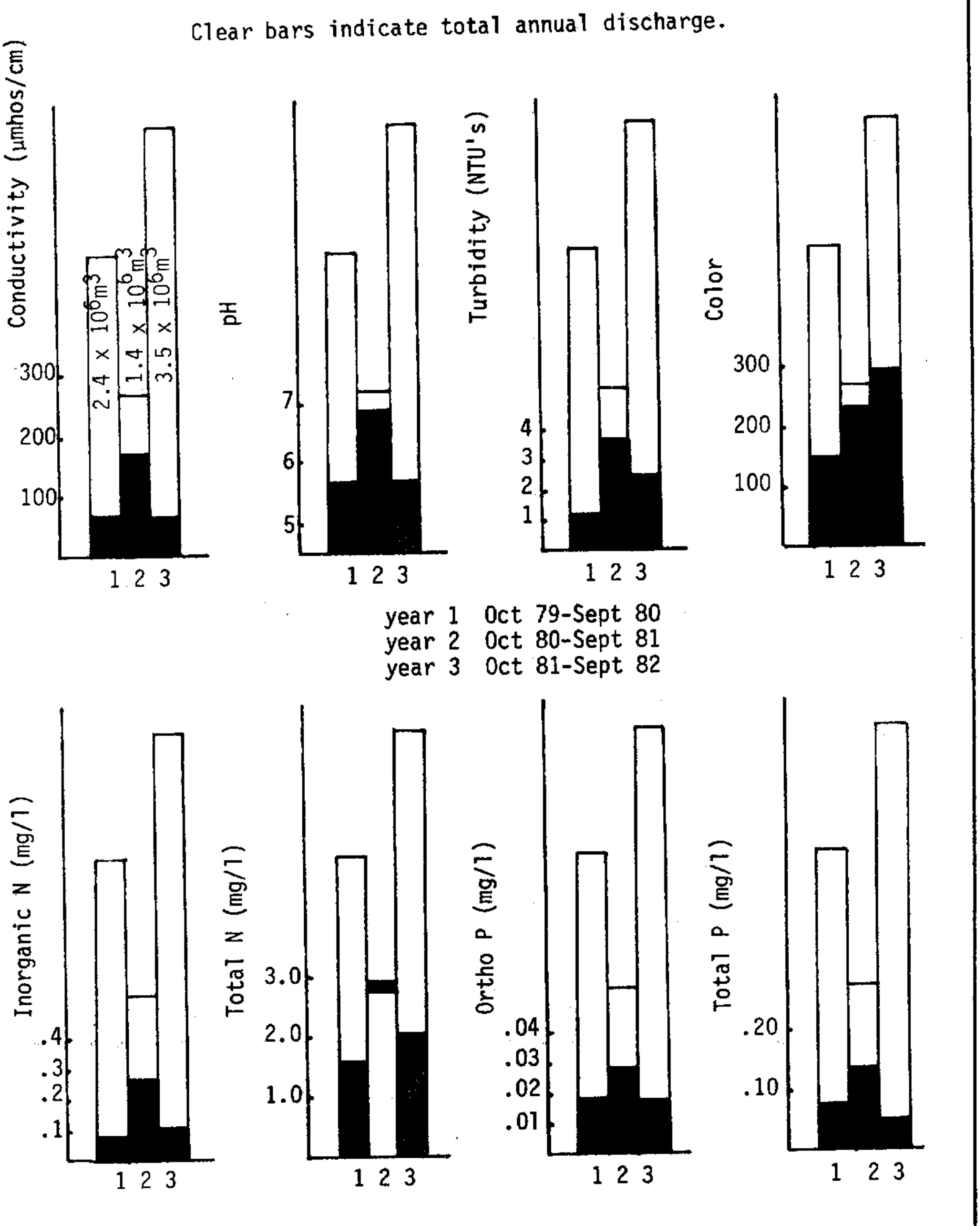
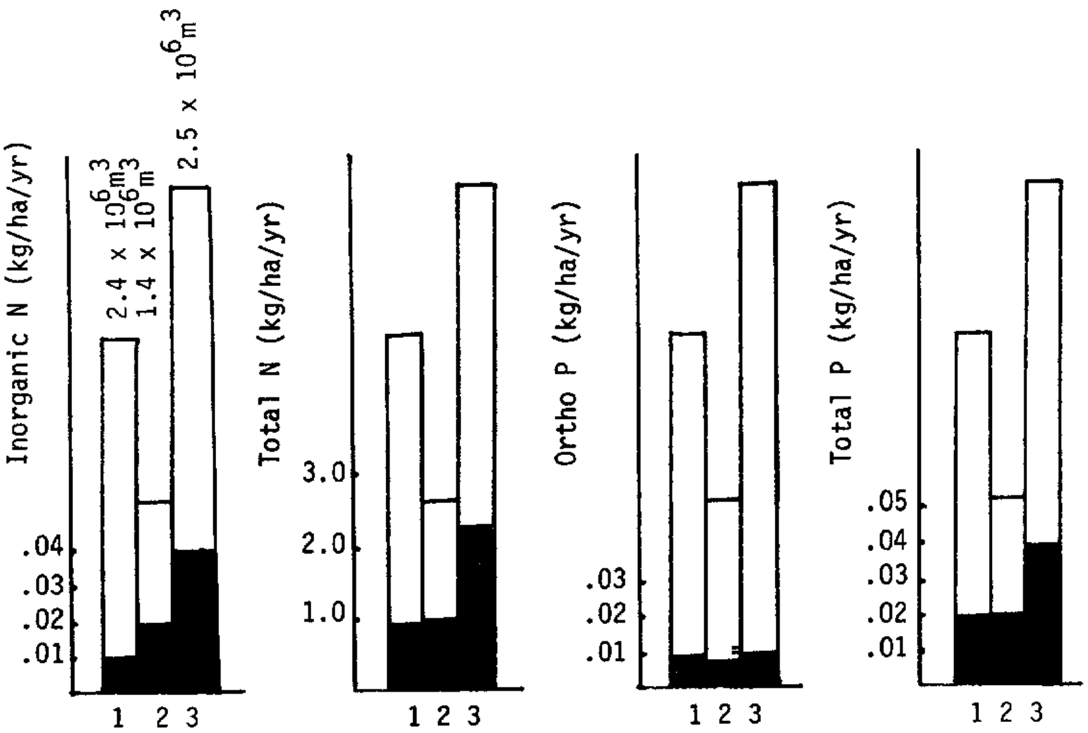


Figure V-23. ANNUAL MEAN CONCENTRATIONS AND TOTAL DISCHARGE AT WILDCAT SLOUGH-EAST WATERSHED

Clear bars indicate total annual discharge.



year 1 Oct 79-Sept 80
year 2 Oct 80-Sept 81
year 3 Oct 81-Sept 82

Figure V-24. ANNUAL MEAN NITROGEN AND PHOSPHORUS EXPORT RATES FROM WILDCAT SLOUGH-EAST WATERSHED

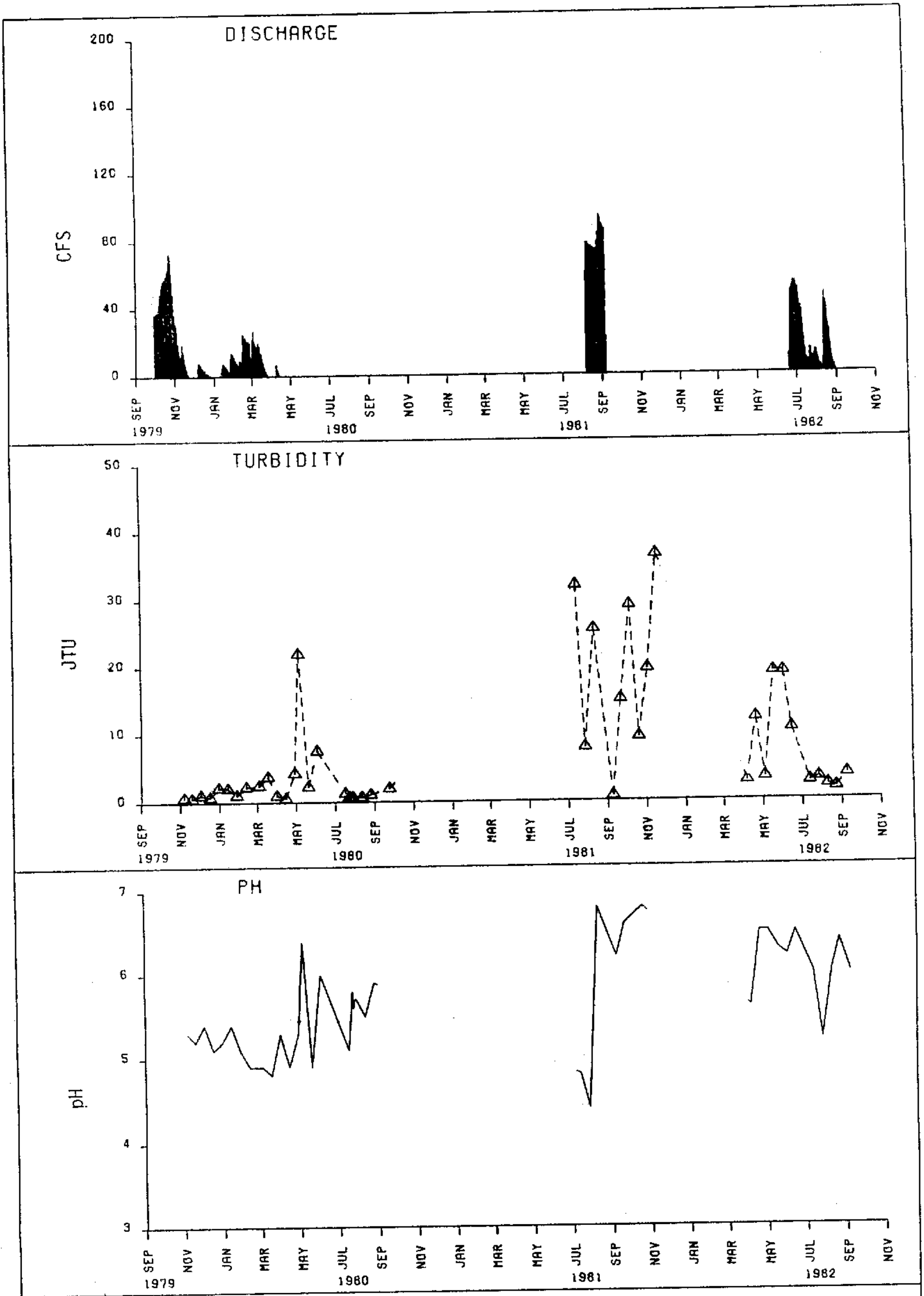


Figure V-25. Time Series Concentrations Wildcat Slough-West (1979-1982) Station 2.

during the four discharge events. Color levels on the other hand tended to decrease during the 1979 event, but actually increased during the two later ones. With the exception of one abnormally high data point (August 1981), conductivity was consistently low (Figure V-26). The general trend was for conductivity to decrease during periods of significant measured discharge.

Total N and total P (Figures V-27 and V-28), as well as their dissolved inorganic components, all exhibited an unexplained but extremely high peak in concentrations during April and May of 1979. This was in direct contrast to lower concentrations that were typical during the remainder of the entire study. Attempts to arrive at an explanation based on cultural pasture maintenance practices have been unsuccessful. The ranch manager when queried about his management practices during or antecedent to this period has indicated that no program or management activity had been conducted that was in any way out of the ordinary. Almost half of the total N peak could be attributed to the dissolved inorganic N fraction which reached concentrations as high as 18 ppm. During the remainder of the study, concentrations were usually at or below detection levels.

The concurrent total P peak was almost entirely made up of the ortho component. Subsequent to May 1979, ortho P was at or below detection limits.

During May and June of each year (with the exception of 1981 when no water was present at the monitoring station), there was a slight increase in total N and total P concentrations but none were of near comparable magnitude to those noted in 1979. These latter cases were all characterized by increases in the particulate constituents (probably largely organic) and no significant increases in the dissolved inorganic fractions were observed.

Wildcat Slough - West Loading/Export

Like the eastern watershed, this portion of the Wildcat Slough study site also acted as an efficient nutrient sink. As before, this was due largely to relatively small loads of predominantly aeolian origin. In addition, relatively small amounts of runoff and discharge occurred during the study period and thus the ground surface was able to absorb almost all of the rainfall and associated nutrient load. During each of the three years of study, the annual rainfall absorption on the land was estimated to be at least 95 percent or greater. Inorganic N and ortho P were taken up in percentages greater than rainfall absorption indicating that uptake of these nutrients by vegetation or adsorption by sediment was actively occurring in addition to that which was being passively lost through absorption of fluid in the soils.

Percentage of total P uptake by the watershed was similar to that noted for rainfall absorption and storage. It appears that those mechanisms and subsequent loss to groundwater or other fates are the primary mechanisms of total P uptake.

Total N uptake is about 90 percent or greater during each year of the study; however, the uptake efficiency is less than that of the rainfall fluid uptake efficiency. This suggests that for some reason, the watershed is less efficient in the uptake of particulate N than it is for the other nutrient species of interest. The channel in which the monitoring station is situated drains a large area of wetlands immediately adjacent to a dense oak/palmetto hammock. It is possible that the wetland is less efficient in absorption of total N than the surrounding pastures. There is also the possibility that some N is being lost through leaching from wetland soils.

With the exception of ortho P, export rates of nutrients from the watershed in kg/ha/yr (Figure V-30) appears to be strongly dependent on and related to the measured amount of runoff.

WILDCAT SLOUGH - TOTAL WATERSHED

The Wildcat Slough west and east watershed just discussed, along with the additional 2,100 ha watershed downstream, all ultimately discharge into C- 41A through a series of five large corrugated metal culverts. The impact of the entire Wildcat Slough watershed on discharge contribution and nutrient export to the C-41A receiving waters was calculated and compared with the results obtained for the two discrete contributing subunits.

Mean annual specific conductance, pH, and turbidity levels all tend to decrease during periods of discharge (Figures V-31 and V-32). These trends are similar to those observed in the two contributory subwatersheds. Peak conductivity levels are somewhat higher at the main outfall location during no-flow periods but fall to magnitudes similar to those noted at the other stations during discharge periods. Turbidity at the main outfall more closely resembles levels observed at the east watershed monitoring locale than the higher ones noted at the western site. Livestock access to the former two sites is more restricted than at the latter one. Agitation of the sediment from occasional livestock activity is probably the primary reason turbidities at that station are greater than those at the other two sites.

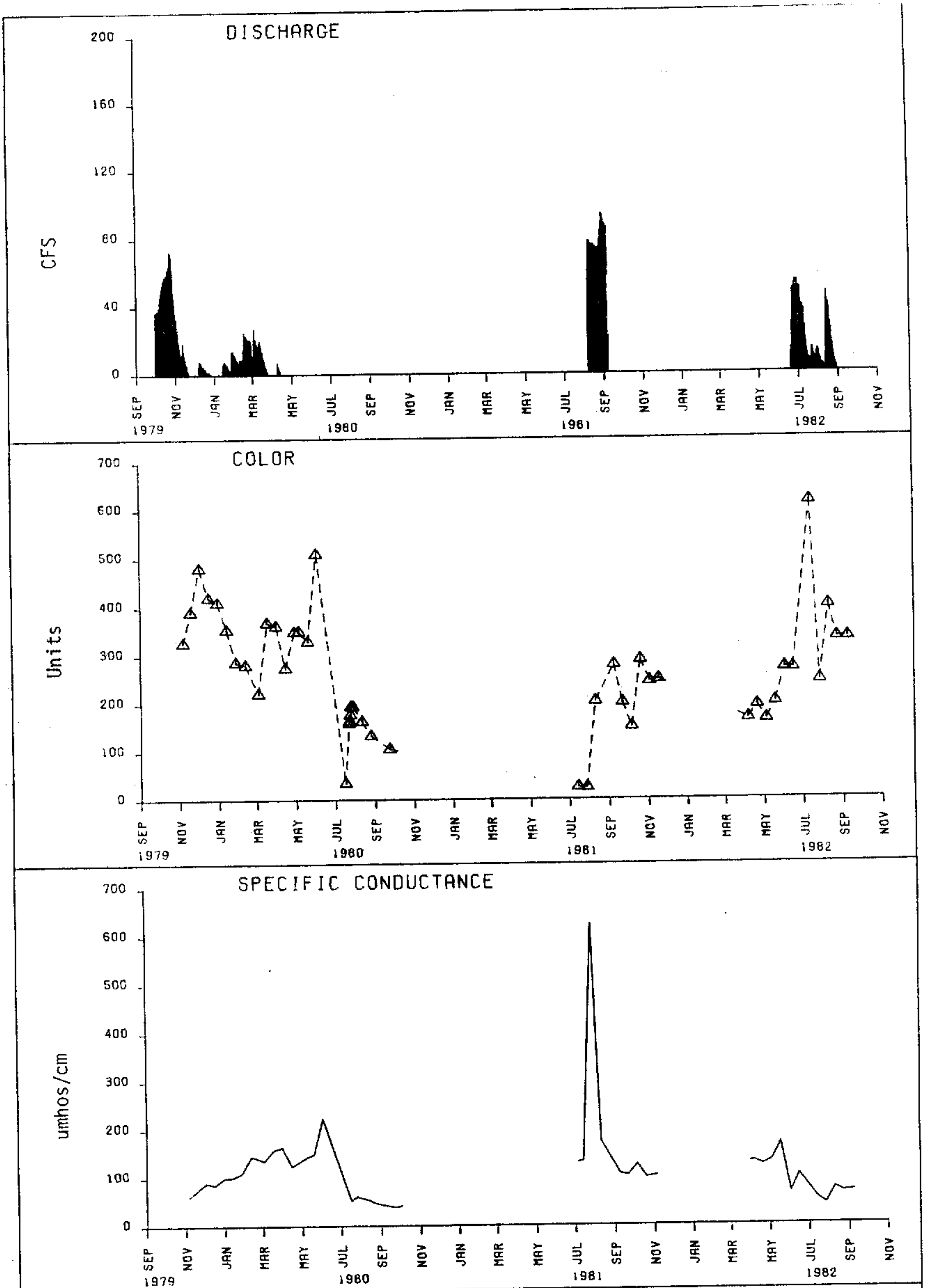
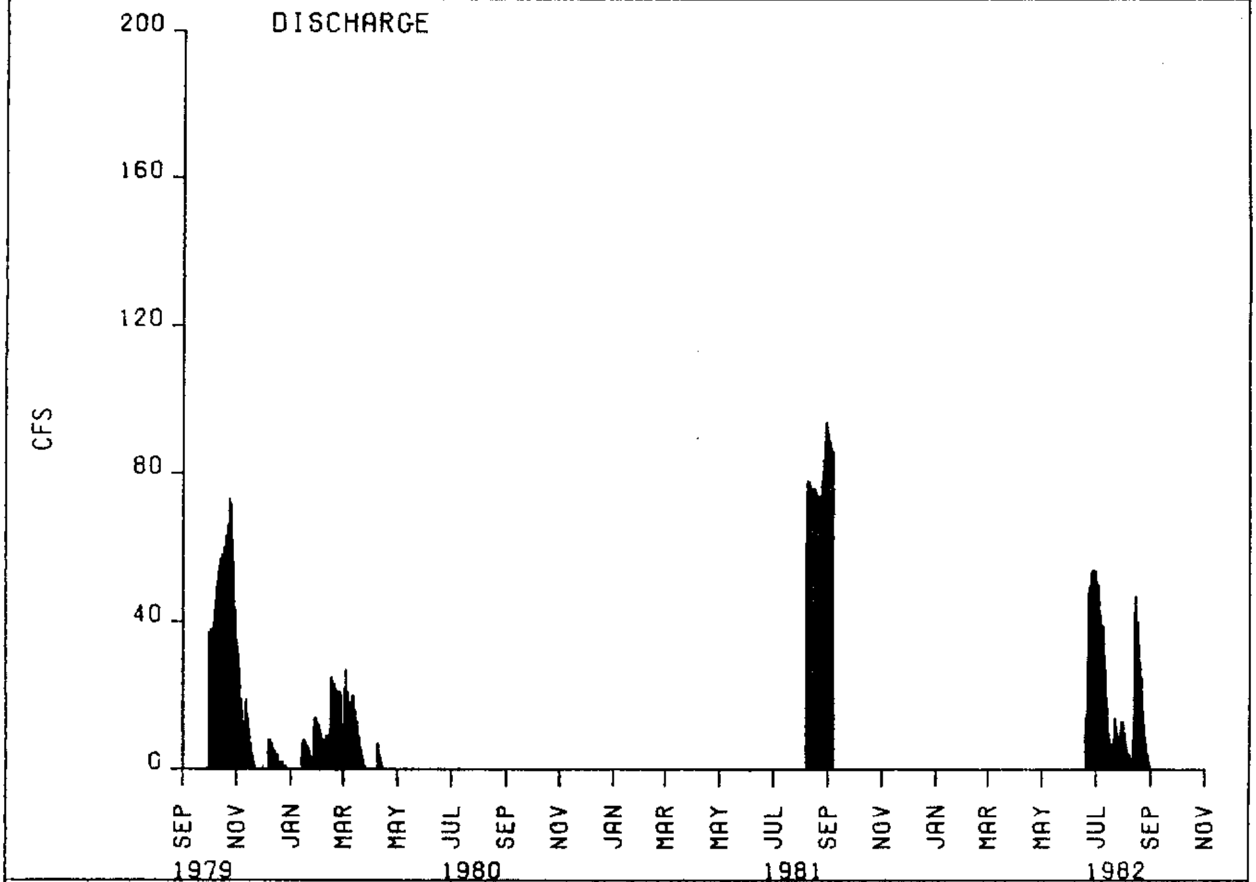


Figure V-26. **Time Series Concentrations** Wildcat Slough-West (1979-1982) Station 2.



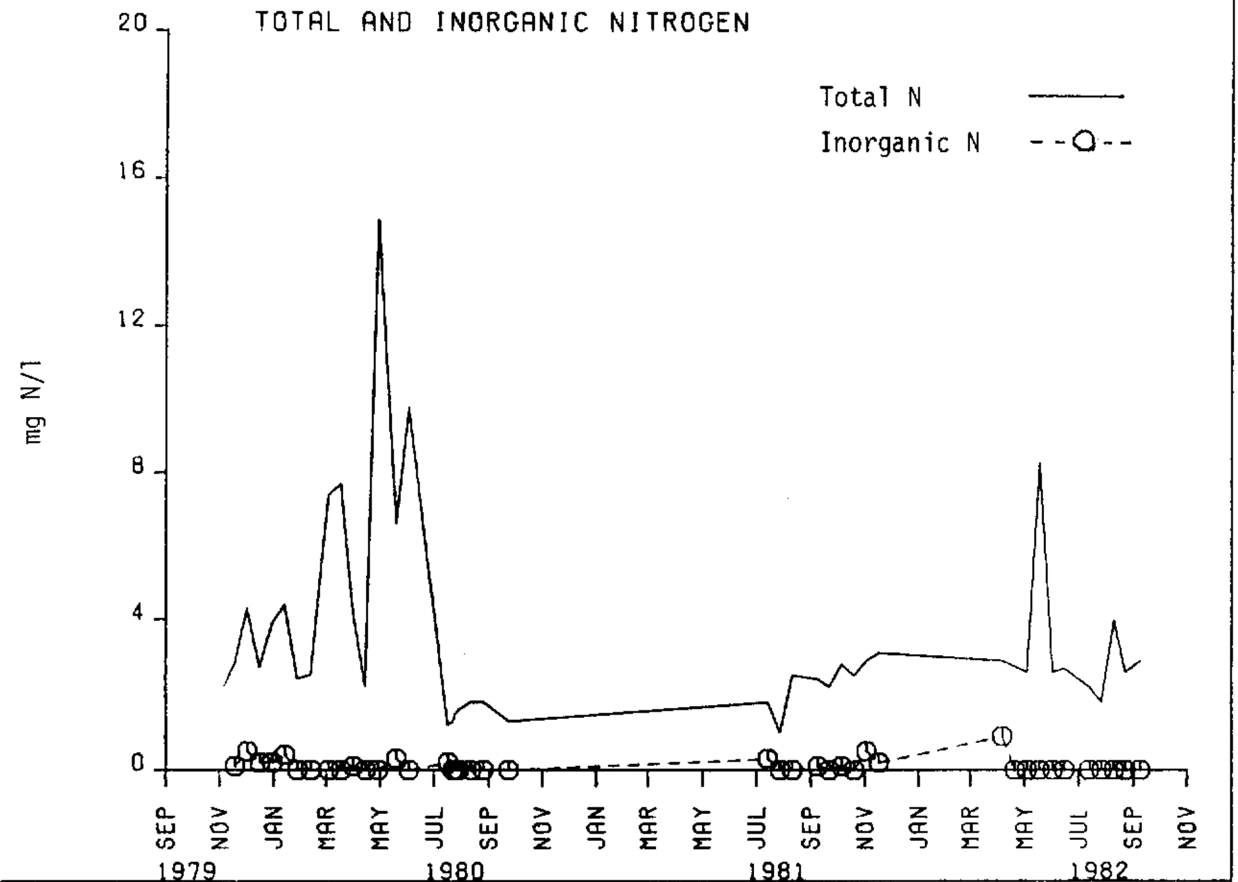


Figure V-27. Time Series Concentrations Wildcat Slough-West (1979-1982) Station 2.

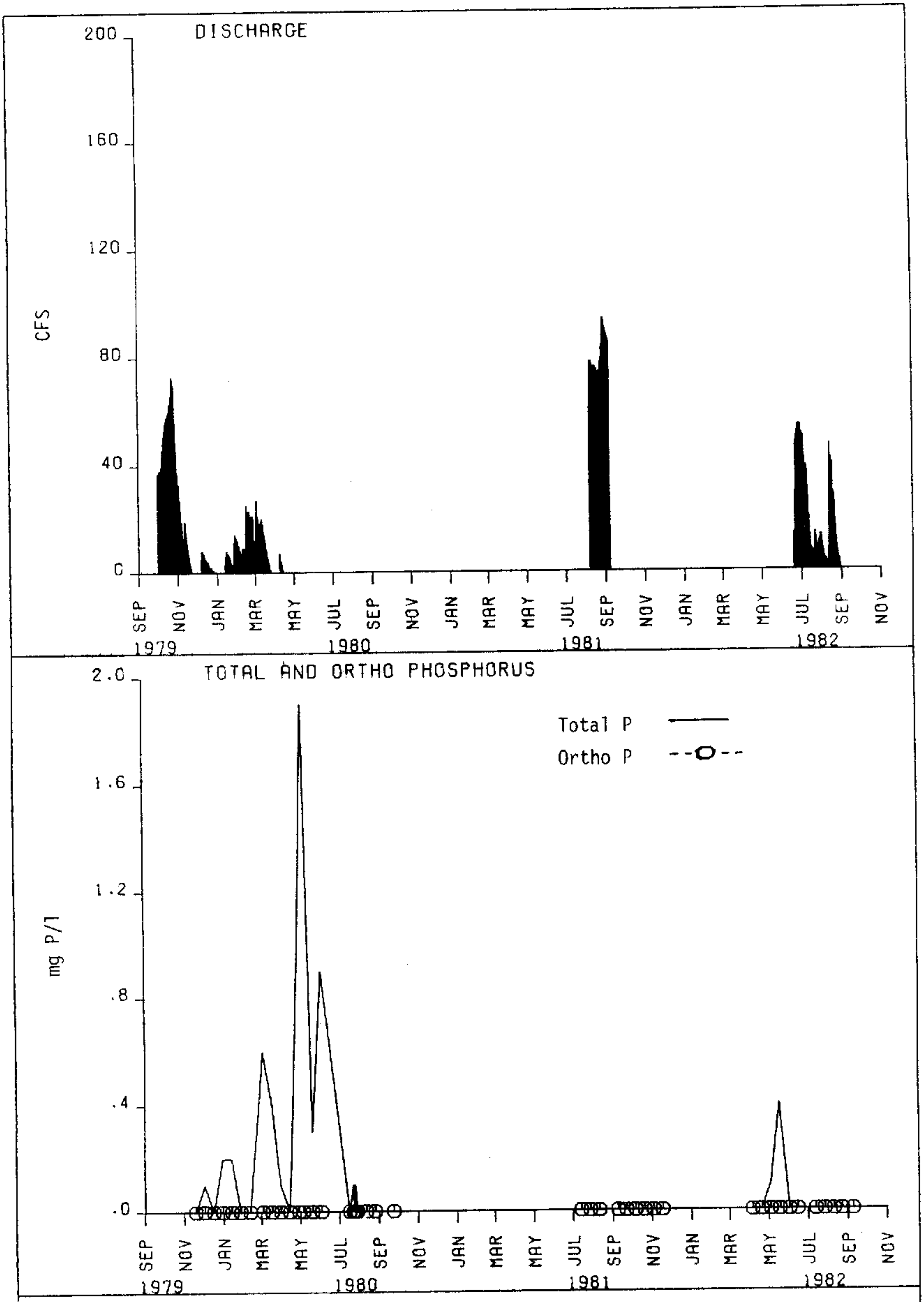


Figure V-28. Time Series Concentrations Wildcat Slough-West (1979-1982) Station 2.

year 1 Oct 79-Sept 80
year 2 Oct 80-Sept 81
year 3 Oct 81-Sept 82

Clear bars indicate total annual discharge.

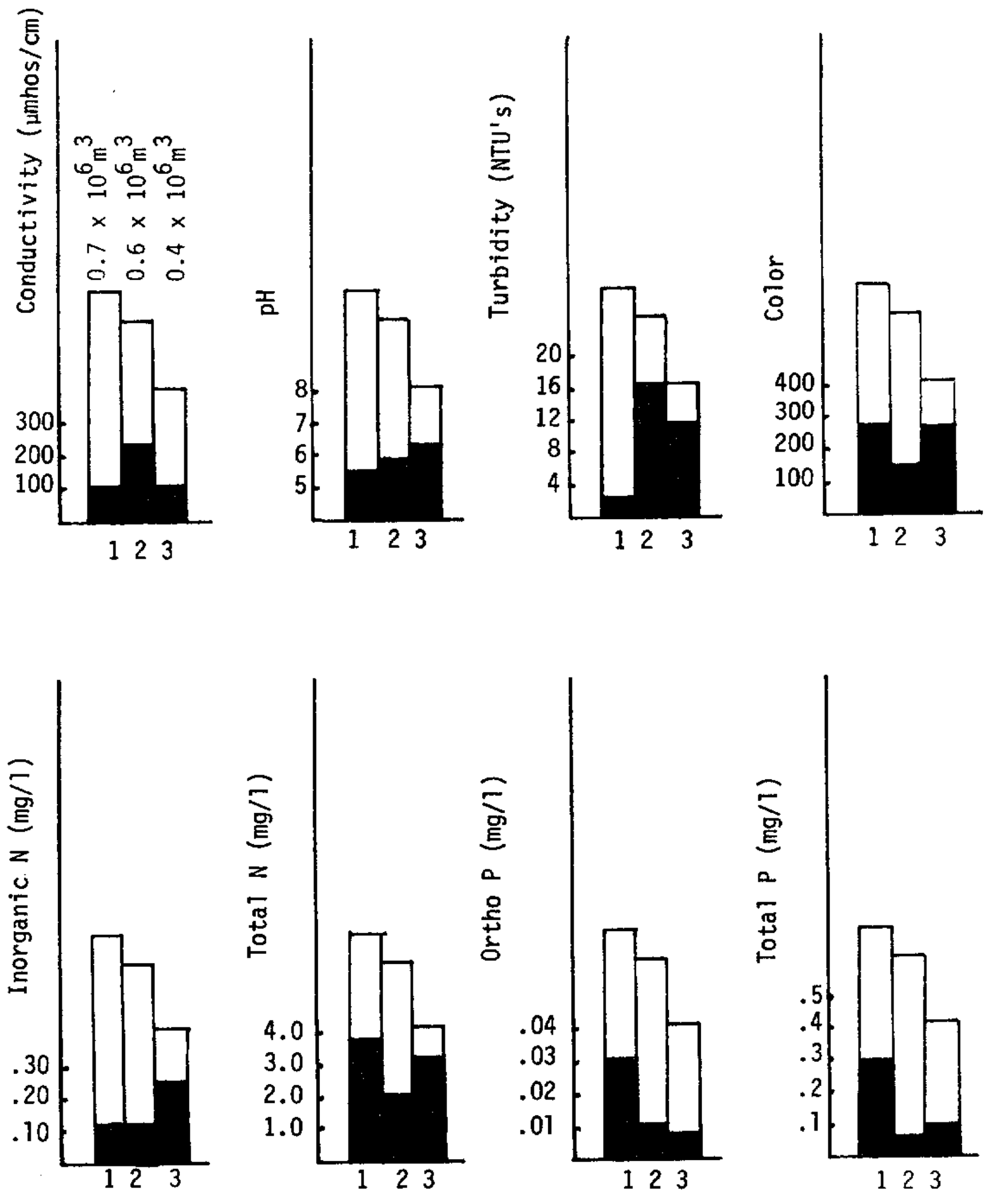
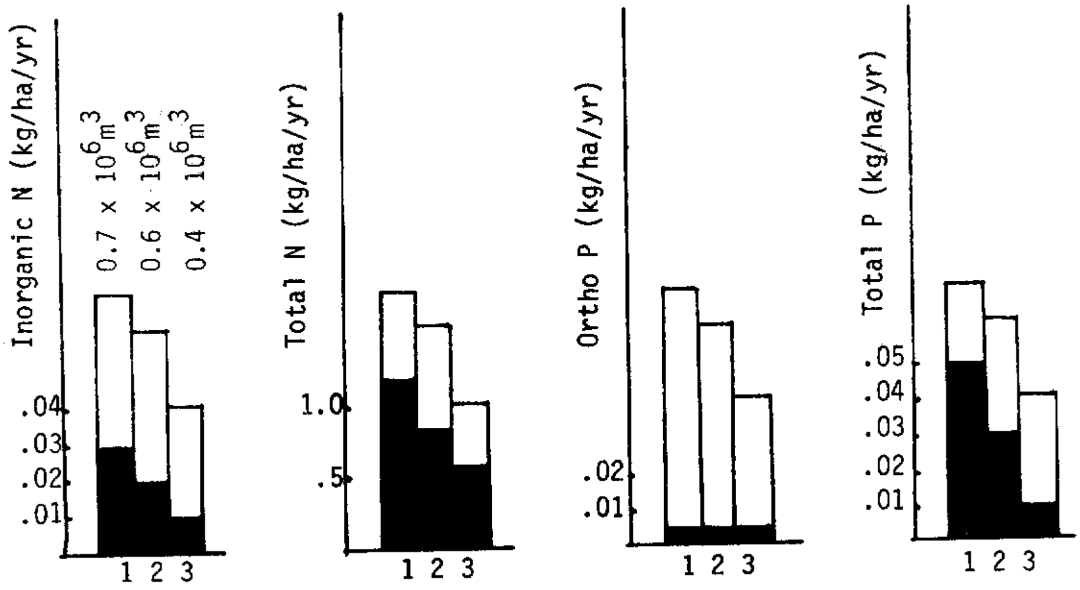


Figure V-29. ANNUAL MEAN CONCENTRATIONS AND TOTAL DISCHARGE AT WILDCAT SLOUGH-WEST WATERSHED

Clear bars indicate total annual discharge.



year 1 Oct 79-Sept 80
year 2 Oct 80-Sept 81
year 3 Oct 81-Sept 82

Figure V-30. ANNUAL MEAN NITROGEN AND PHOSPHORUS EXPORT RATES FROM WILDCAT SLOUGH-WEST WATERSHED

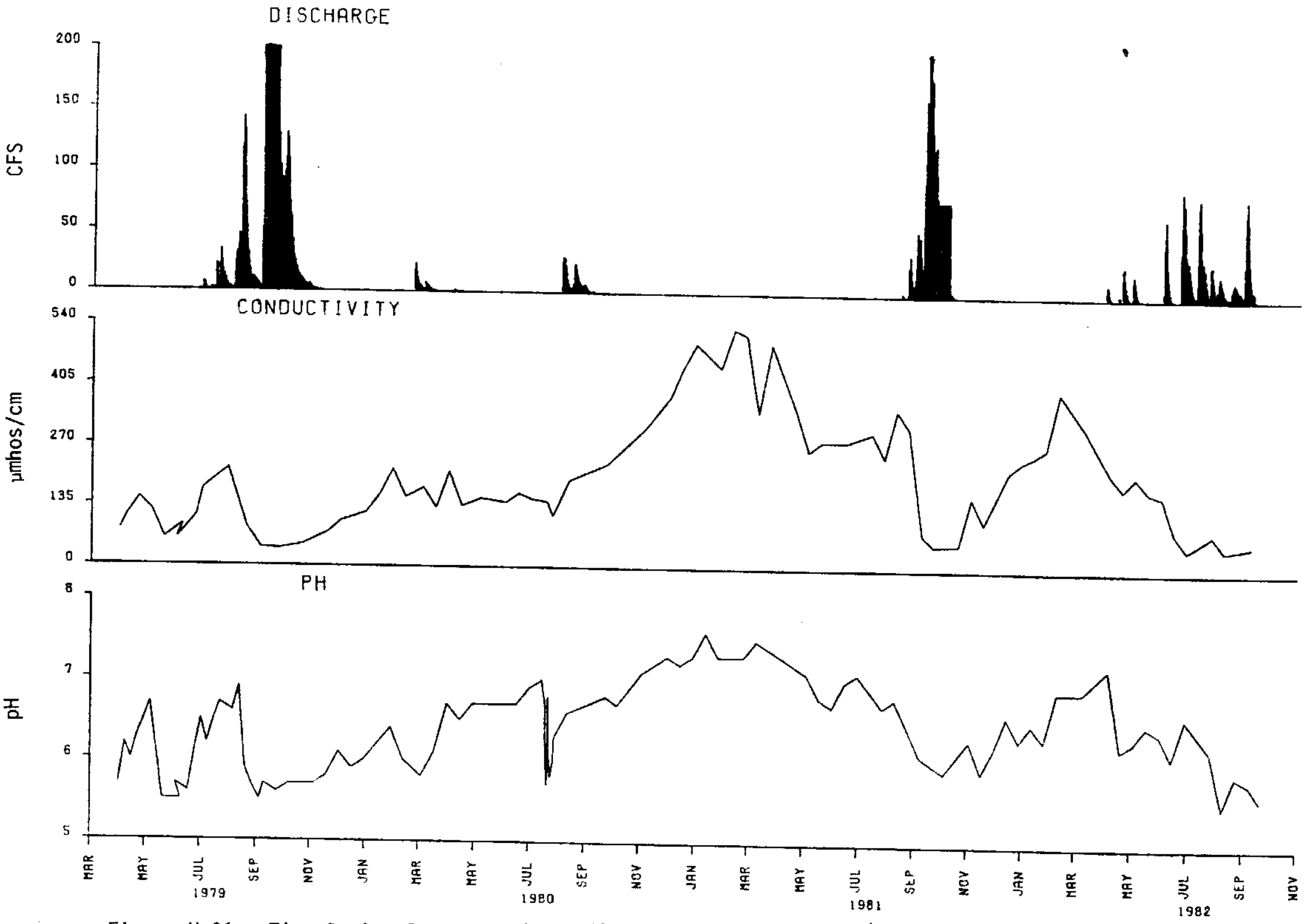


Figure V-31. Time Series Concentrations Wildcat Slough Watershed (1979-1982) Station 1.

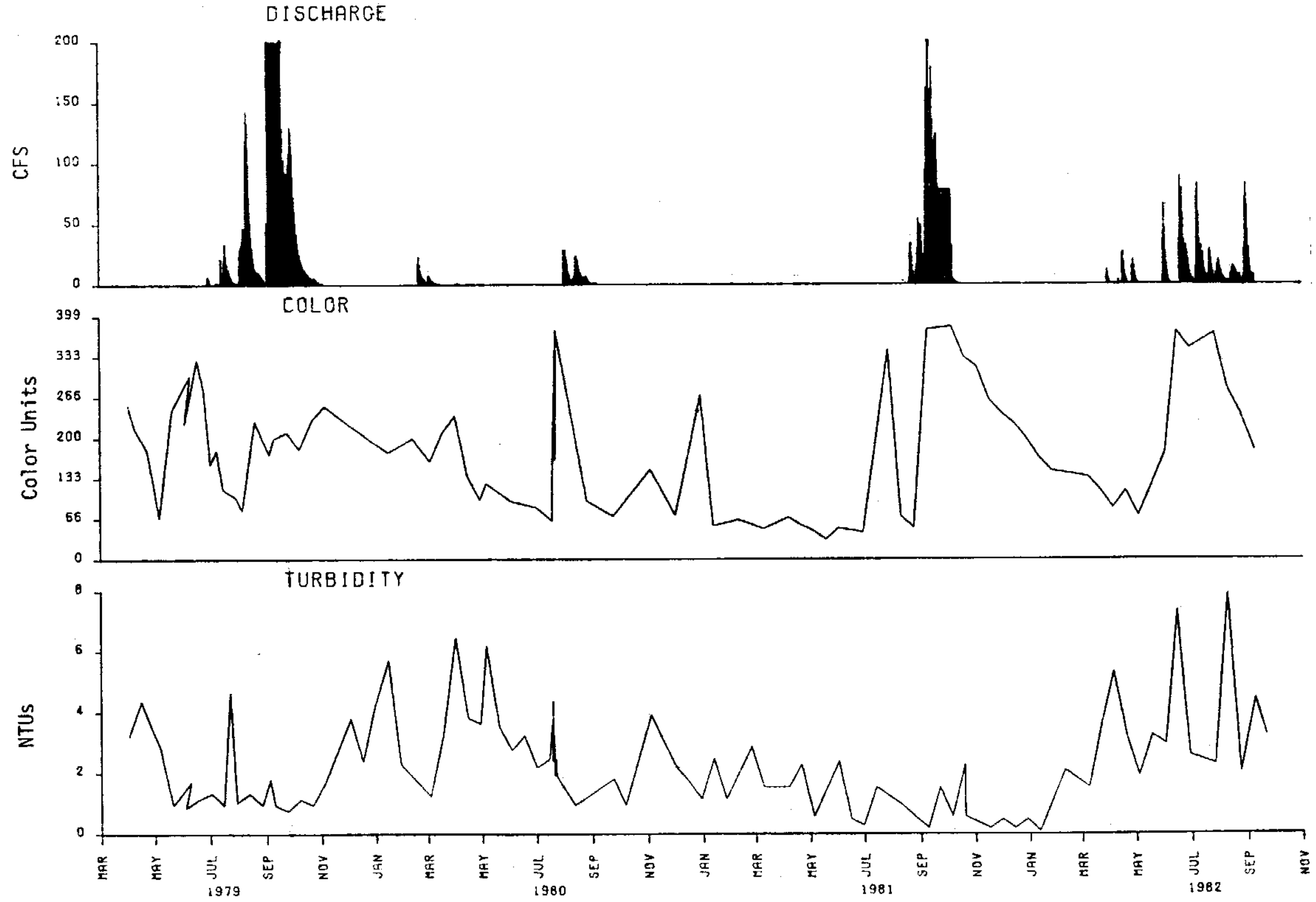


Figure V-32. Time Series Concentrations Wildcat Slough Watershed (1979-1982) Station 1.

Nitrogen and phosphorus concentrations are depicted in Figures V-33 and V-34. Ortho P and dissolved inorganic N concentrations at the main outfall station were all near or below detection limits. Total N and total P concentrations were of a magnitude more similar to those noted in discharge coming from the east watershed than those coming from the western watershed.

As a rule, quality of discharge from the entire Wildcat Slough site was more similar to that noted from the eastern watershed than that observed coming off the western watershed. The characteristics of the area between the subwatershed monitoring sites and the main site outfall appears to be more similar to the eastern watershed. In addition, direct animal access to the stream at the monitoring site is equally restricted, therefore, less chance exists of introducing extraneous conditions that could tend to bias the results.

Water and nutrient budgets were calculated for the intermediate watershed using estimated rainfall amounts and nutrient contributions along with measured streamflow and loads entering from the two tributary channels. Inorganic N and ortho P loads (Table V-2) were reduced in excess of reduction of flow; therefore, it can be concluded that active uptake processes on the watershed and/or in the stream channel were occurring. Percent of total N and total P uptake, however, more closely resemble, and in some cases are less than, percent fluid reduction in the system, and thus one can conclude that the bulk of N and P mass lost is merely the result of storage or absorption in the soils.

ASH SLOUGH - EAST

Time Series Data:

Flat topography and indistinct boundaries have rendered it almost impossible to delineate the total surface area of this watershed. It has been estimated by various persons to cover between 26 to 75 acres (10.5 - 30.4 hectares). For the purpose of performing loading calculations, uptake and export rates, the convenient figure of 50 acres (20.2 ha) has been chosen as it lies midway between the two extremes and is most likely to allow one to achieve a perspective that is of the proper order of magnitude. There are no drainage improvements or ditches on this tract of land and once the ground is saturated, water runs across the slightly sloping surface as sheetflow towards the interceptor ditch surrounding the detention/retention marsh.

Saturated soils are a requisite for runoff from the watershed to occur. During the 36-month study period of record, there were 20 months in which there was no measurable runoff from the watershed. As one would expect, discharge from the watershed characteristically exhibits seasonal patterns, occurring predominantly during the months of the historical wet season. Runoff phenomena during the study were characterized by what can best be described as two relatively normal years interrupted by one extreme abnormally dry year. During that year (1980-81), measurable runoff occurred only during one month.

Though conductivity and pH levels were somewhat variable during the periods when water was present at the sampling station (Figure V-35), the

TABLE V-2. ANNUAL PERCENTAGE REDUCTION OF NUTRIENTS AND FLOW FOR THE WILDCAT SLOUGH WATERSHED AS MEASURED AT THE OUTFALL TO C41-A

	1979-80	1980-81	1981-82
Total Water Reduction	41.9	97.8	62.9
Inorganic N	95.6	99.9	98.1
Total N	48.7	98.2	43.4
Ortho P	88.3	99.5	95.3
Total P	78.2	98.6	56.7

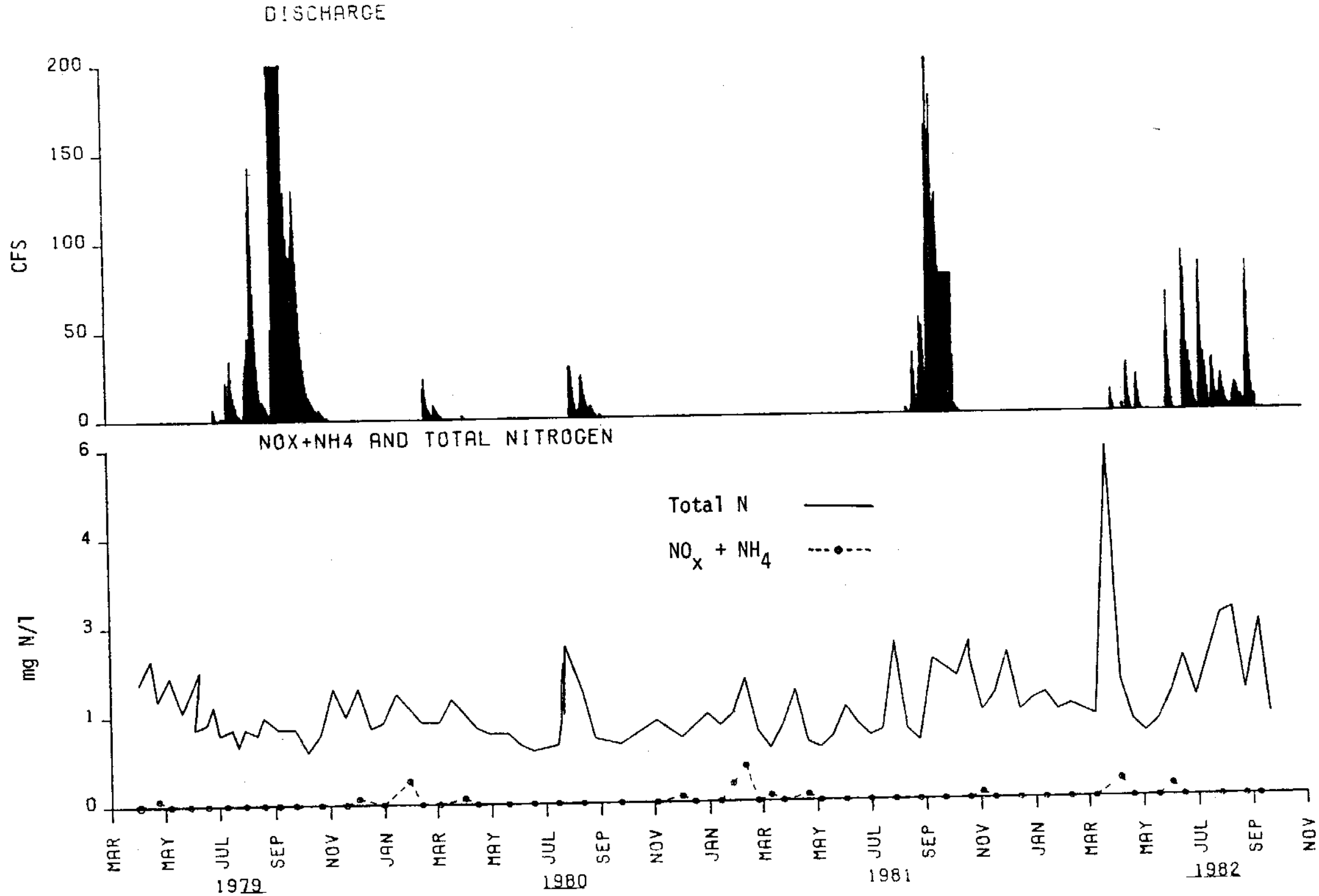


Figure V-33. Time Series Concentrations Wildcat Slough Watershed (1979-1982) Station 1.

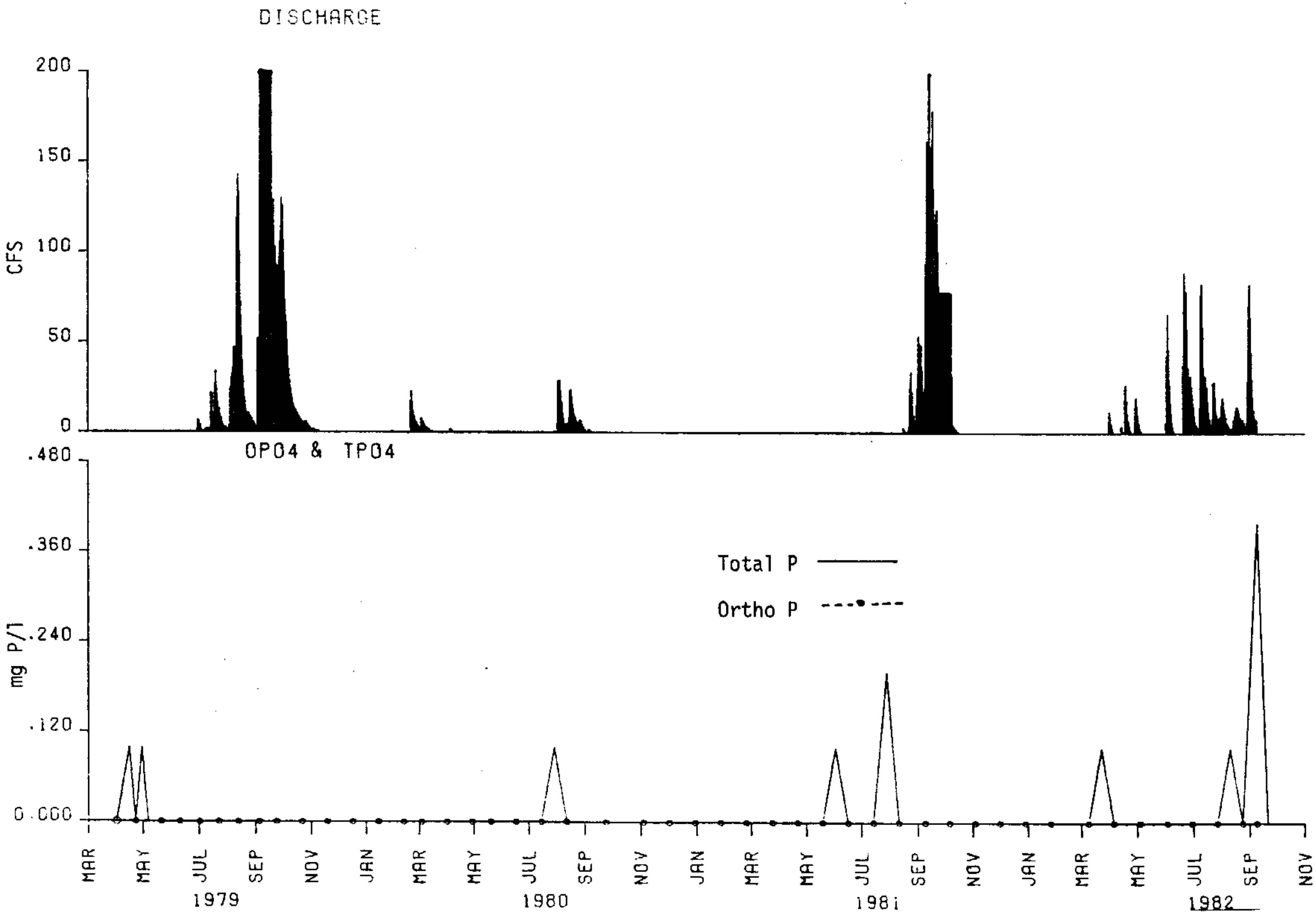


Figure V-34. Time Series Concentrations Wildcat Slough Watershed (1979-1982) Station 1.

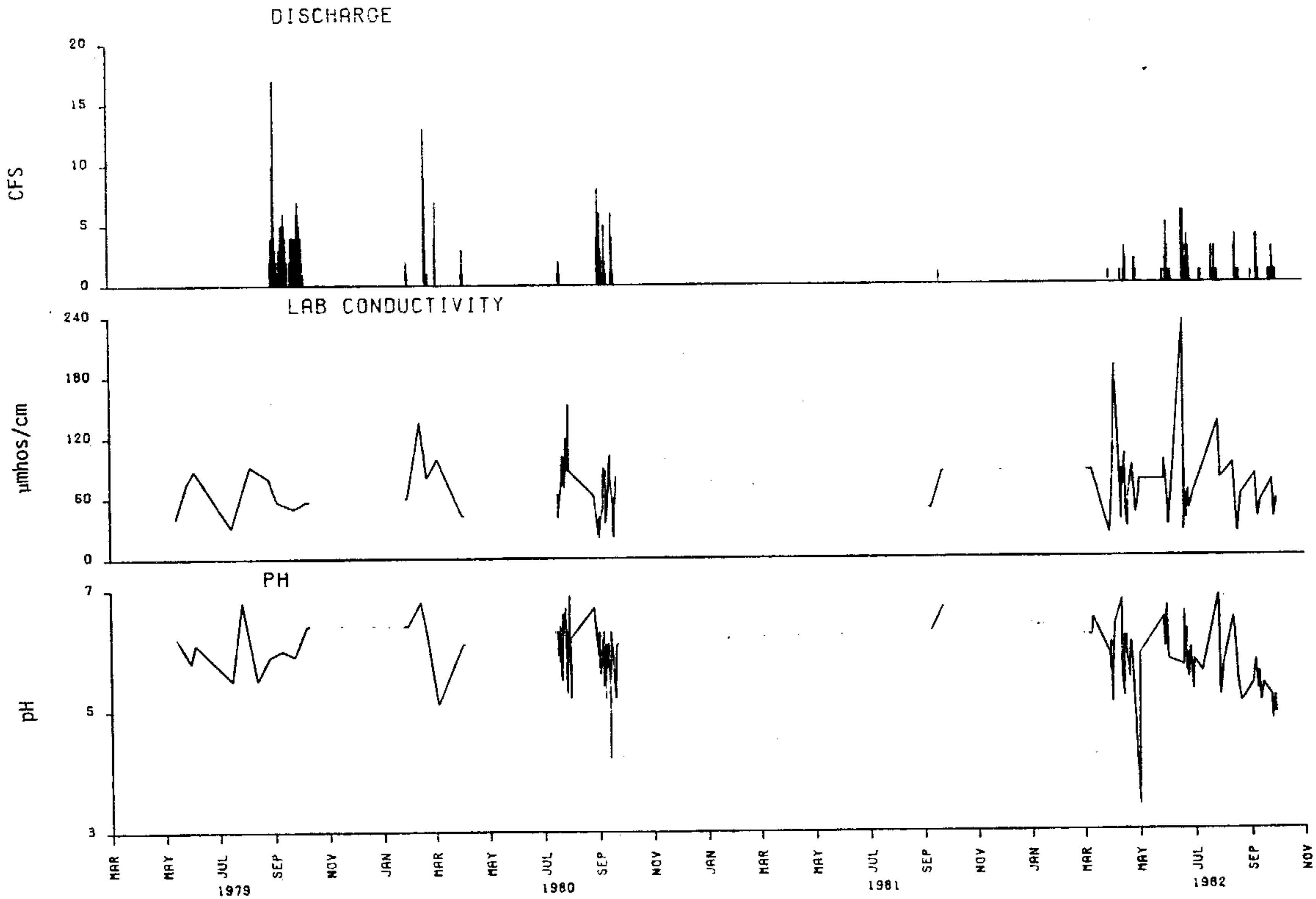


Figure V-35. Time Series Concentrations Ash Slough-East Watershed (1979-1982) Station 4.

mean annual concentrations were similar for all three years (Figure V-39). Conductivity remained low and pH was consistently slightly acidic. Color and turbidity levels (Figure V-36) likewise exhibited some variability. On a mean annual basis, color was similar for the two normal years and slightly greater during the interceding dry period. Mean turbidity levels were similar during the first two years and about three times higher during the final year of the study.

Dissolved inorganic N was a very small and insignificant portion of the total N measured in the discharge (Figure V-37). Both inorganic N and total N concentrations remained relatively constant, with the exception of noticeable peaks in particulate N that coincided with the onset of measurable discharge. Mean annual time series concentrations of both the dissolved inorganic and total N components were similar for all three years (Figure V-39) and did not appear to be related to the quantity of annual discharge.

Unlike nitrogen, the dissolved ortho component was the predominant species of the phosphorus load being washed from the watershed (Figure V-38). Concentrations were variable during individual discharge events, but for the most part oscillated within similar ranges for each event. For whatever reason, mean concentrations of ortho and total P during the final year of the study period were roughly half of those noted during the previous two years. No explanation for this was apparent other than the fact that rainfall and discharge during the wet season of the last year was drawn out over a longer time span than either of the previous two. This may have provided the opportunity for stored phosphorus on the watershed to be washed out and depleted over time as reflected by low concentrations occurring late in the season. This phenomenon did not appear to occur for any of the other monitored constituents.

Ash Slough - East Loading/Export

According to the landowner, cultural loading of N and P on this watershed through chemical fertilizer application, though practiced in the past was reported not to have occurred during the course of this study. Nutrient loadings on this watershed were assumed to be either aeolian in origin or deposited in fecal matter left by cattle. Since cattle should theoretically harvest nutrients by grazing, that amount redeposited on the watershed through manure should not be considered as additional load since it is merely a converted form of that which was originally tied up as vegetable matter. Nutrient loadings then were considered to be strictly aeolian in origin.

During the three years of the study, the watershed was a net sink for N and P loads attributable from atmospheric inputs. Dissolved inorganic N was absorbed almost totally as no measurable amounts were noted in runoff. During the drought year when so little runoff occurred, all N and P species were, for all practical purposes, entirely absorbed on the land.

Mean annual N and P export rates are depicted in Figure V-40. Total N export rates appear to be somewhat dependent on total annual discharge, while total and ortho P export rates may be dependent on other factors Export rates for the P species were roughly three times greater during the first year of the study than during the last year, even though total annual discharges were similar.

ASH SLOUGH - WEST

Time Series Data:

Unlike the east portion of the Ash Slough site, the surface area of the western watershed was definitely defined by the outer perimeter of a network of drainage ditches that formed an interconnected grid throughout the area. Also, unlike the eastern watershed, this pasture was fertilized on an annual basis with roughly 300 lbs/acre of 20-10-10 or similar formulation. Fertilizer application was conducted in late October/early November of each year subsequent to the cessation of the wet season.

Like the other Ash Slough site, runoff occurred after antecedent rainfall had been sufficient to saturate the soils. No measurable runoff or discharge occurred during 21 months of the 36-month period of study. The longest continuous period with no measured discharge occurred between October 1980 and August of 1981. Some relatively low amounts were measured in September but the following five months were again dry and no discharge from the watershed was noted. The drought was finally broken in March of 1982 and measurable discharge occurred during each of the remaining months of the study.

Physical parameters measured over the study period are depicted in Figures V-41 and V-42. Conductivity is relatively low (less than 150) particularly during periods of measured discharge. When no discharge is noted but water stands behind the flume, the levels tend to rise in response to concentration by evaporation processes. The pH values remain in the almost neutral range, oscillating between slightly acidic and slightly basic. Lower pH seems to be the rule during periods of measured discharge and mean annual pH values are slightly to the acid side of neutral. During periods of discharge,

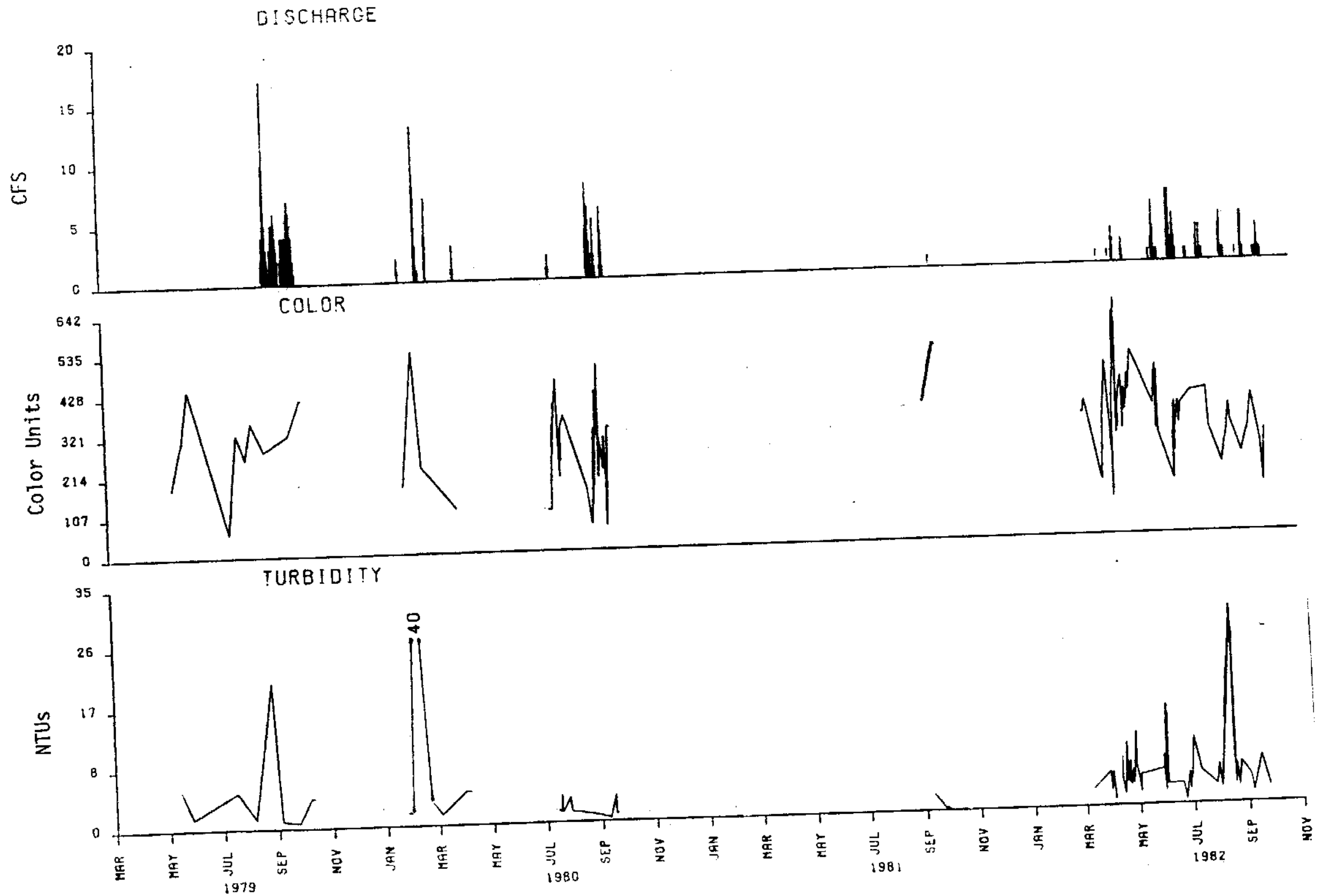


Figure V-36. Time Series Concentrations Ash Slough-East Watershed (1979-1982) Station 4.

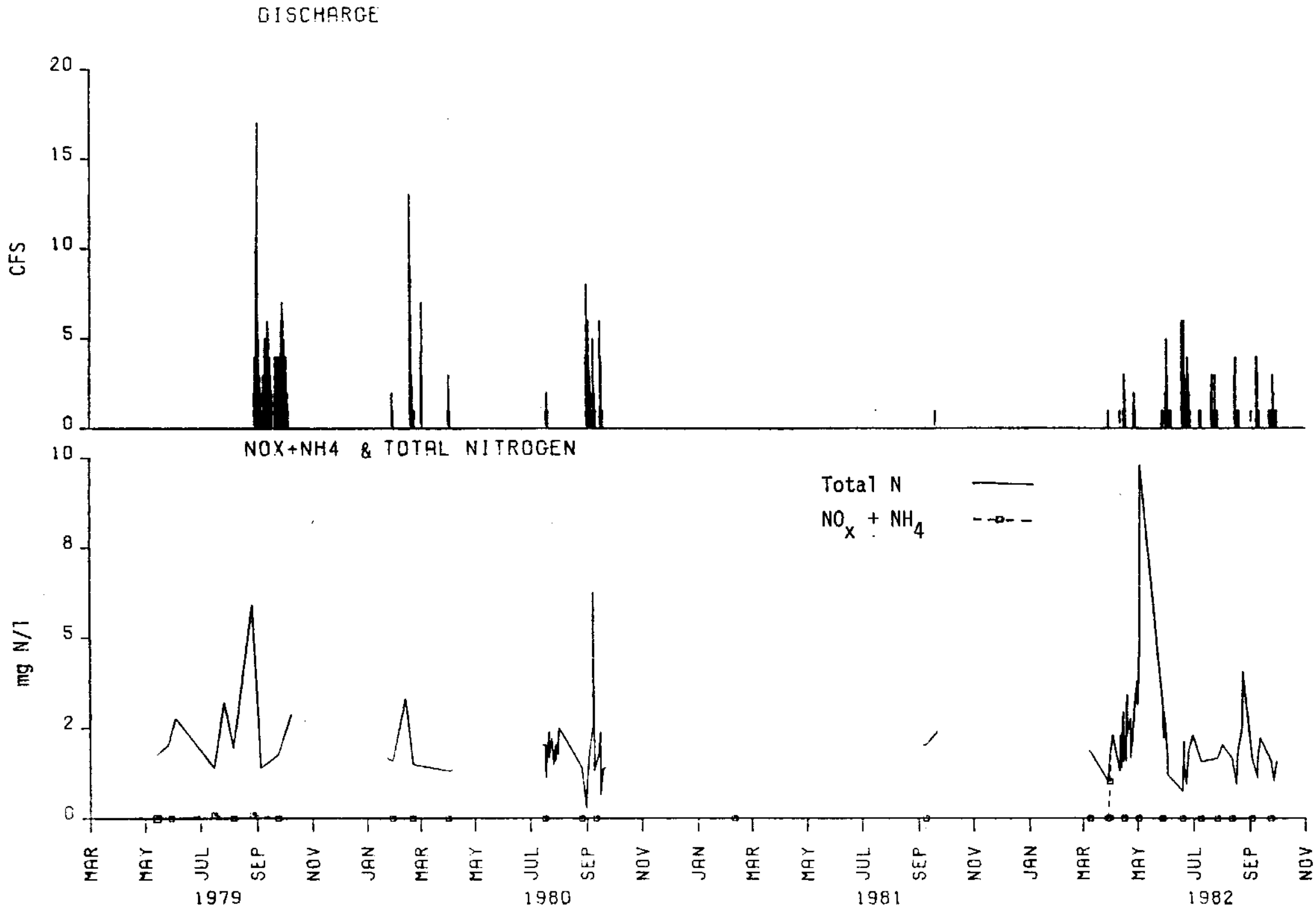


Figure V-37. Time Series Concentrations Ash Slough-East Watershed (1979-1982) Station 4.

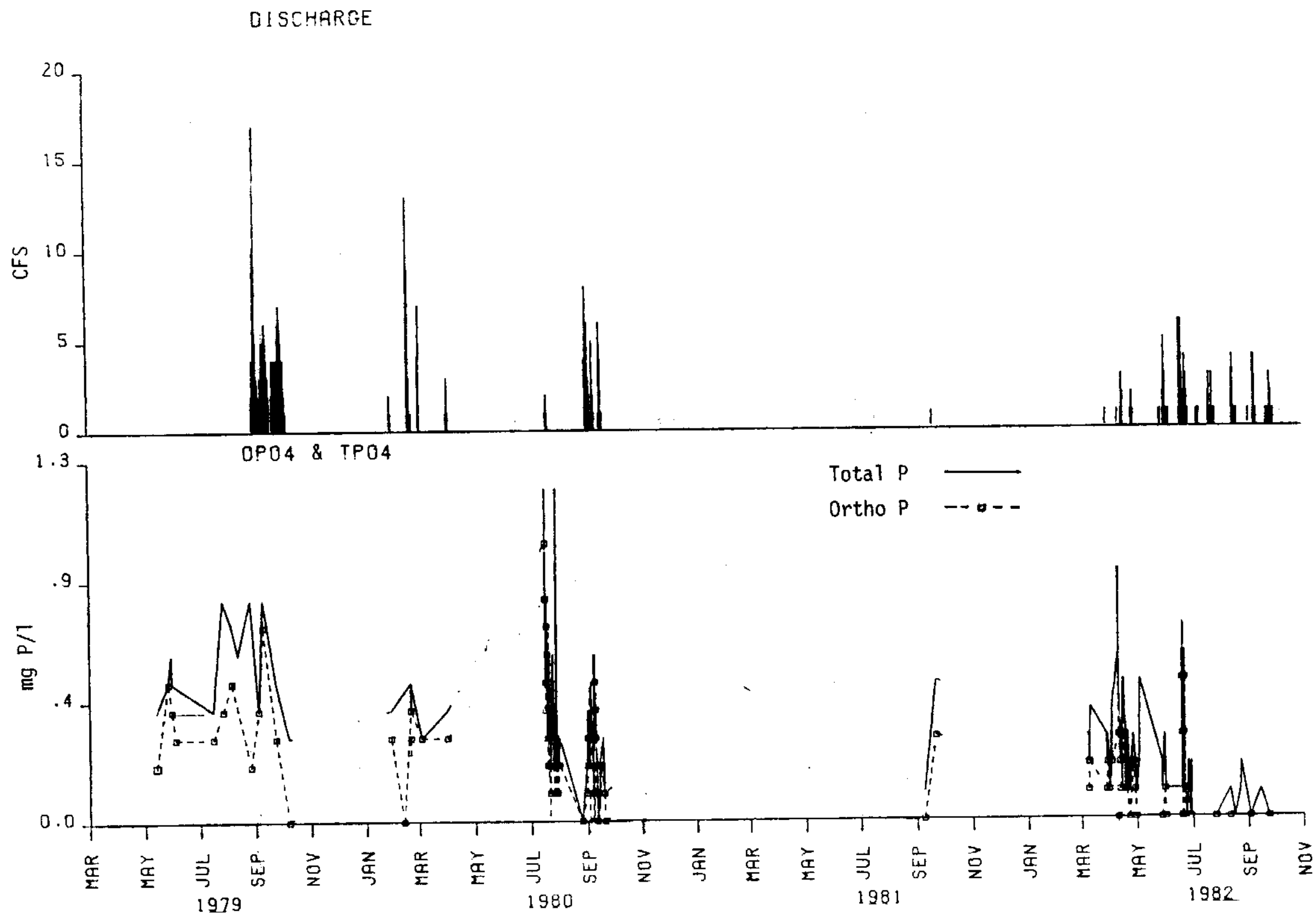


Figure V-38. Time Series Concentrations Ash Slough-East Watershed (1979-1982) Station 4.

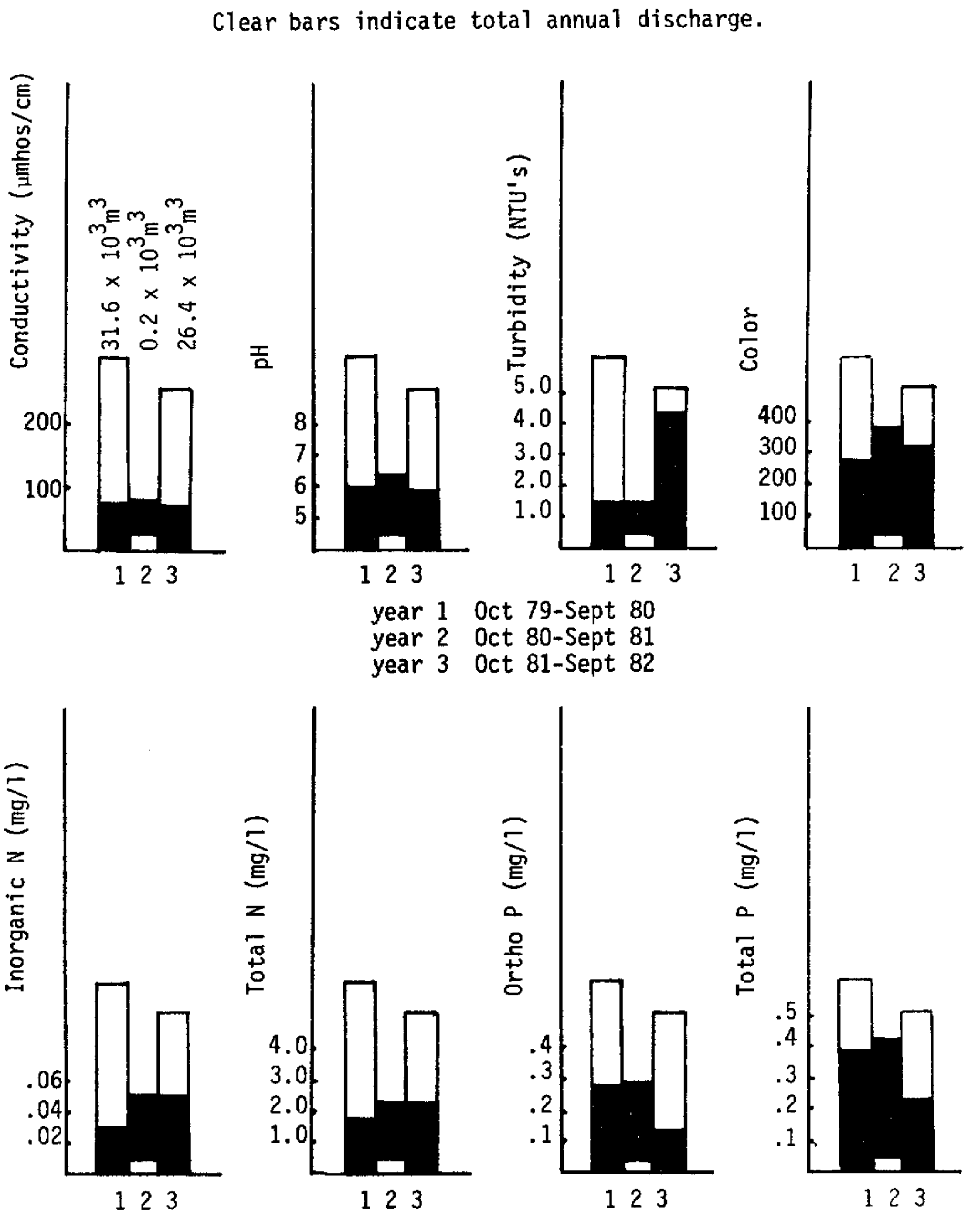


Figure V-39. ANNUAL MEAN CONCENTRATIONS AND TOTAL DISCHARGE AT ASH SLOUGH-EAST (UNDITCHED PASTURE)

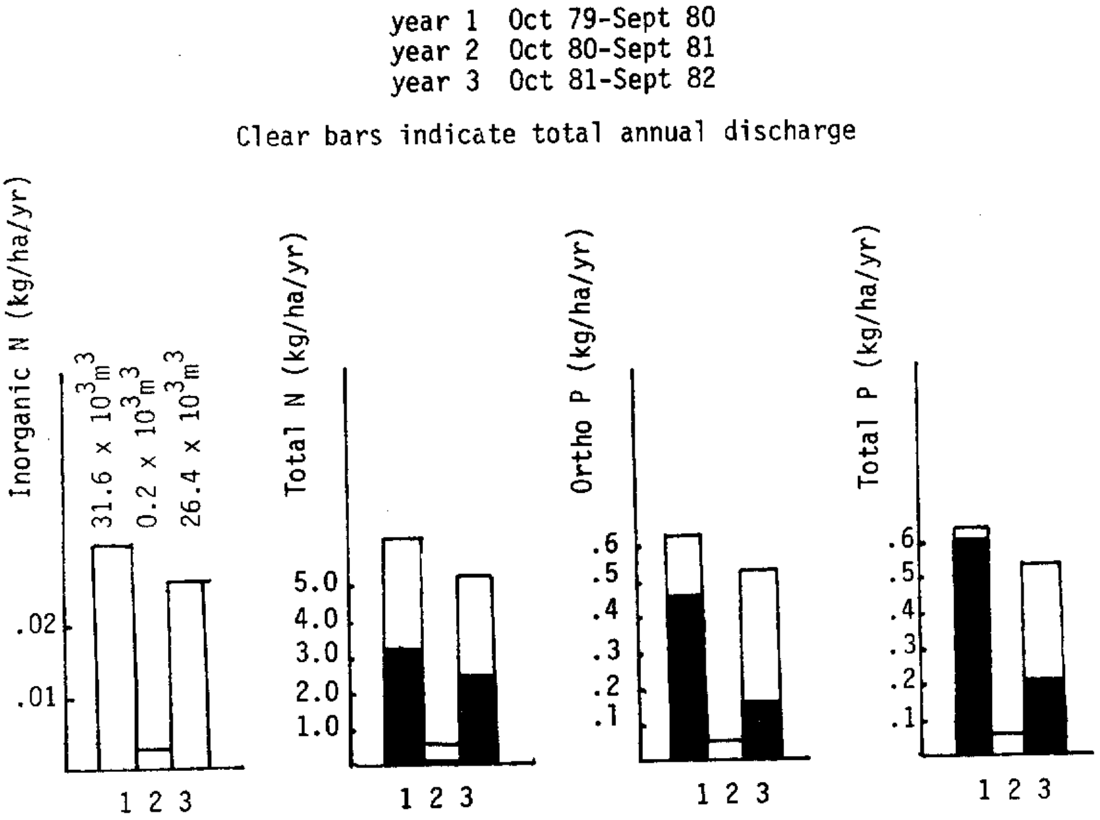


Figure V-40. ANNUAL MEAN NITROGEN AND PHOSPHORUS EXPORT RATES FROM ASH SLOUGH-EAST (UNDITCHED PASTURE)

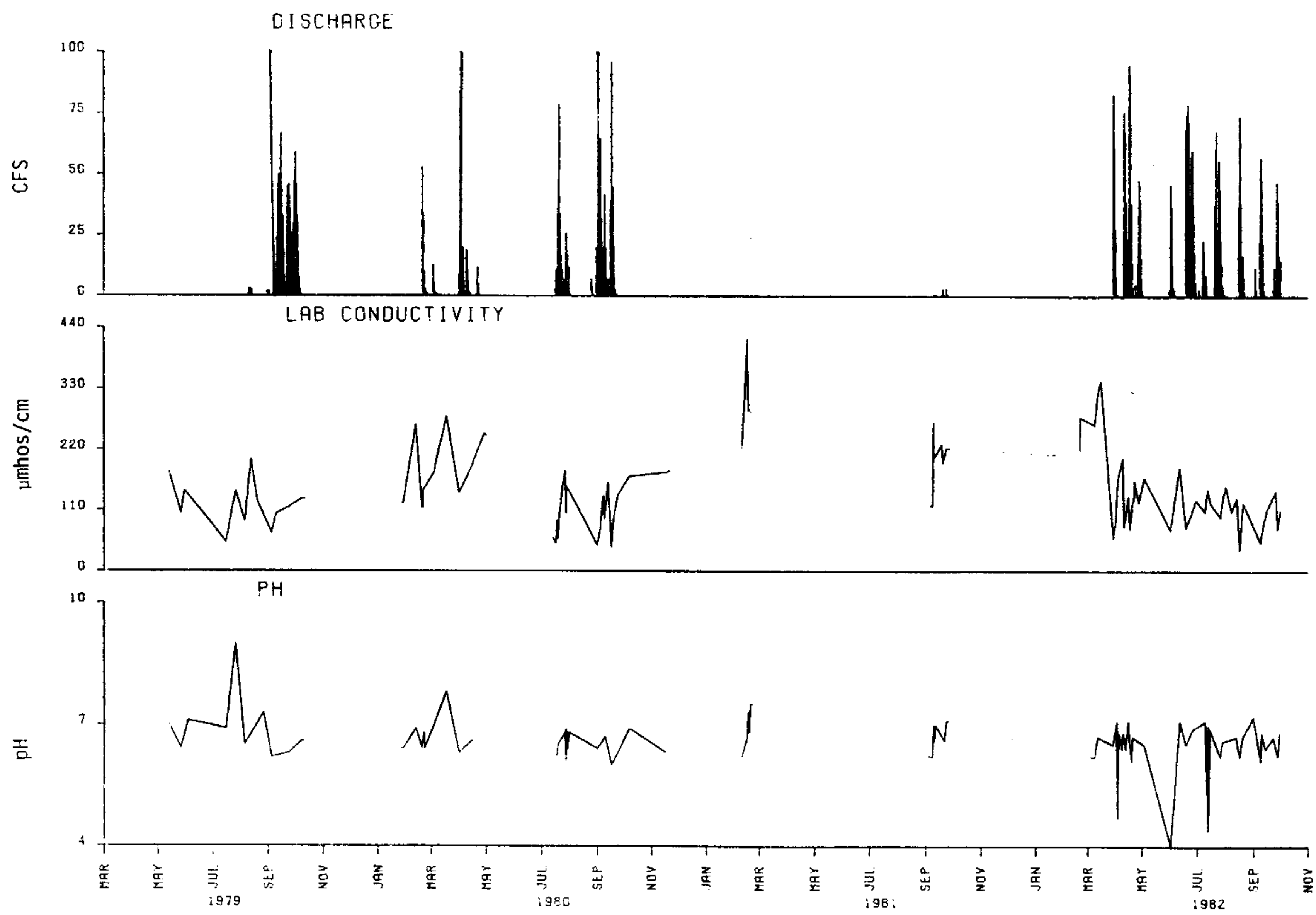


Figure V-41. Time Series Concentrations Ash Slough-West Watershed (1979-1982) Station 2.

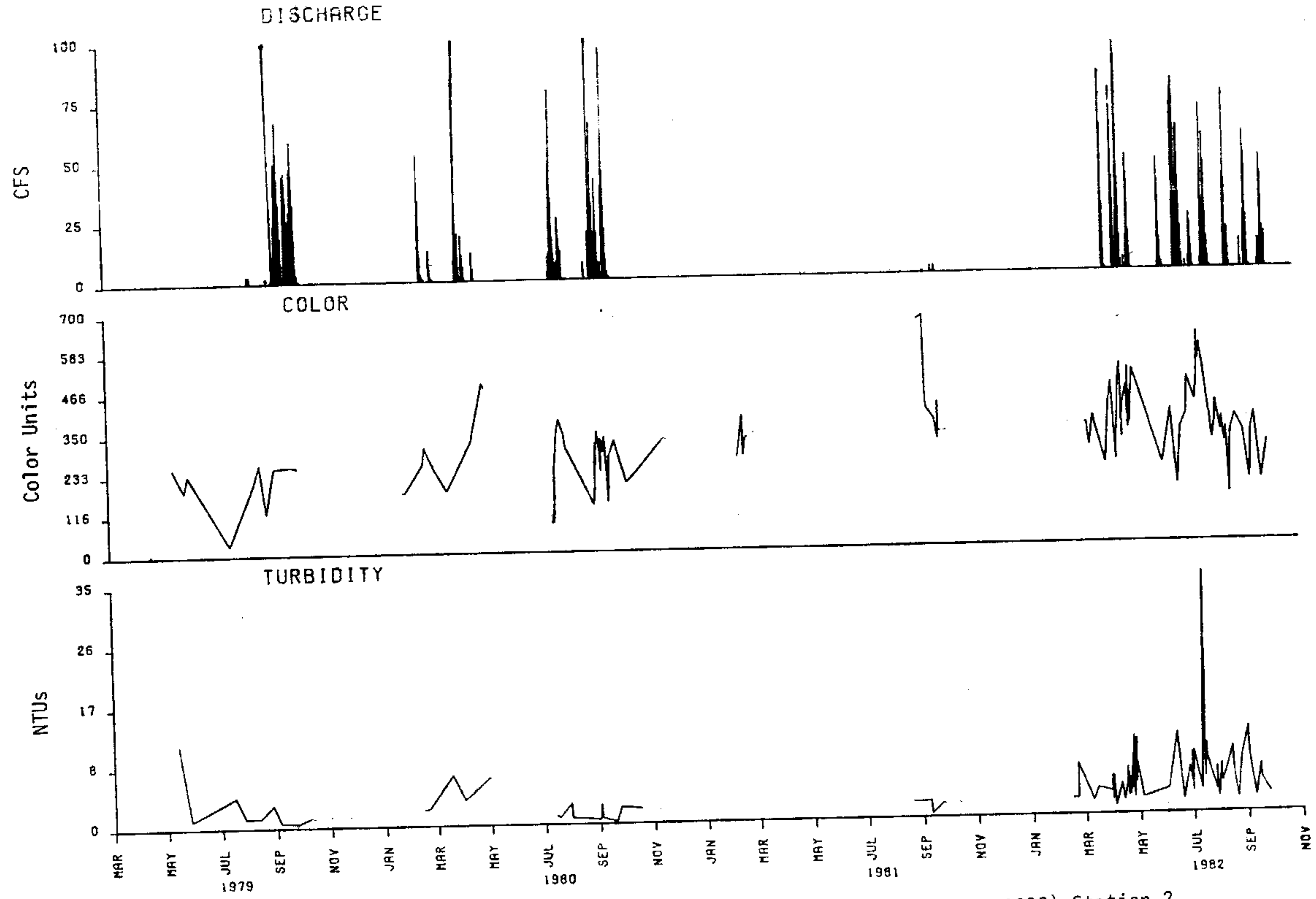


Figure V-42. Time Series Concentrations Ash Slough-West Watershed (1979-1982) Station 2.

color values usually range from about 100 to 500. They appear to be variable over this range and seem to show a positive tendency to increase with increasing volume of discharge. Turbidities as a rule are extremely low (less than 10 NTUs).

Nitrogen and phosphorus time series data are depicted in Figures V-43 and V-44. It is readily evident that N is present in predominantly organic form as dissolved inorganic N species are continually at or below detection limits. Total N concentrations are relatively constant, and with the exception of one aberrant data point in July of 1982, almost always less that 6 ppm. There does not appear to be distinct seasonal trends nor does the application of fertilizer in October/November of each year seem to cause a noticeable impact on concentrations.

Phosphorus concentrations in runoff at this site were the highest noted at any of the rangeland study sites. The dissolved ortho component was the predominant constituent of the P load. On an average annual basis it represented 73 percent of total P concentration during the drought year and from 81 to 95 percent of the total P concentration during the other two normal years. P concentration levels also tend to exhibit seasonal patterns of peaks and declines. Peak concentrations were noted in the early spring of each year (about March) and declined gradually to lowest levels about September. This phenomenon seems to be easily explained by the timing of fertilizer applications by the landowner. As previously noted, fertilizer is added to the watershed annually at the cessation of the wet season. Application at the beginning of the fall dry season is timed to reduce the amount of P washoff and allow maximum time for the applied load to be taken up by the grasses.

For whatever reason (slow P release rate, slow P uptake ability by plants during the winter season, or inability of soils to bind the excess P), once rainfall and subsequent discharge begins, P is flushed from the watershed. In each of the two cases where there was some measured discharge beginning in the spring, high concentrations in the runoff were evident. The concentrations declined throughout the remaining months of the year with lowest levels being reached prior to November. The low base line levels were 16 to 20 times lower than the observed peaks. Obviously, the practice of fertilizer application impacts the quality of runoff (especially P) leaving this watershed.

Mean annual concentrations of N do not appear to be influenced by the total amount of discharge for any one year, while on the other hand, mean annual P concentrations seem to be somewhat influenced by annual measured discharge totals during each of the three years of this study (Figure V-45).

Ash Slough - West Loading/Export

Nitrogen and phosphorus loadings on this watershed are derived from atmospheric input and annual application of 300 lb/acre of 20-10-10 or similar formulation fertilizer. Atmospheric input is estimated to make up less than 20 and 3 percent of the total annual N and P loads, respectively.

The watershed served as a net sink for both N and P. It was particularly effective in uptake of N, removing more than 99 percent of the total inorganic N load during each year. If one assumes that the applied fertilizers were eventually released in this form, then N uptake was especially effective. There was a net uptake of total N during each year, but the level of efficiency was substantially less during the two years of more normal rainfall amounts. Eighty-four percent and 78 percent of the total N loads applied were taken up. Since most of this total N load can be assumed to have been at least temporarily in a dissolved inorganic state, this probably is indicative of a conversion of the inorganic N to organic particulate material by the pasture vegetation and some loss of particulate organic N through dissolution of leaf litter or other organic material such as decomposed cattle manure, etc.

Dissolved P is not absorbed as efficiently as is dissolved inorganic N. During the two wet years, ortho P uptake efficiency was estimated to be about 80-83 percent as opposed to almost 100 percent for inorganic N. Uptake of total P ranges from 77-80 percent for the same two years. If one assumes that culturally applied P in fertilizer eventually is released in a dissolved reactive form, then there is, in addition to uptake on the watershed, some evidence of conversion to particulate organics that are being given off either as decomposed leaf litter, manure, or some other organic material.

Mean annual N and P export rates are depicted in Figure V-46. As previously noted, a small amount of discharge during the month of September was the entire total for the second year of study. Estimated export rates were low to nonexistent since there was no conveyance mechanism. During the remaining two normal years, export rates for N and P species were relatively similar. Export rates for N species appeared to be somewhat positively correlated and dependent on total discharge. P species on the other hand did not seem to reflect this phenomenon. It may be that annual export rates of P could be positively correlated with total discharge to the point where unbound P

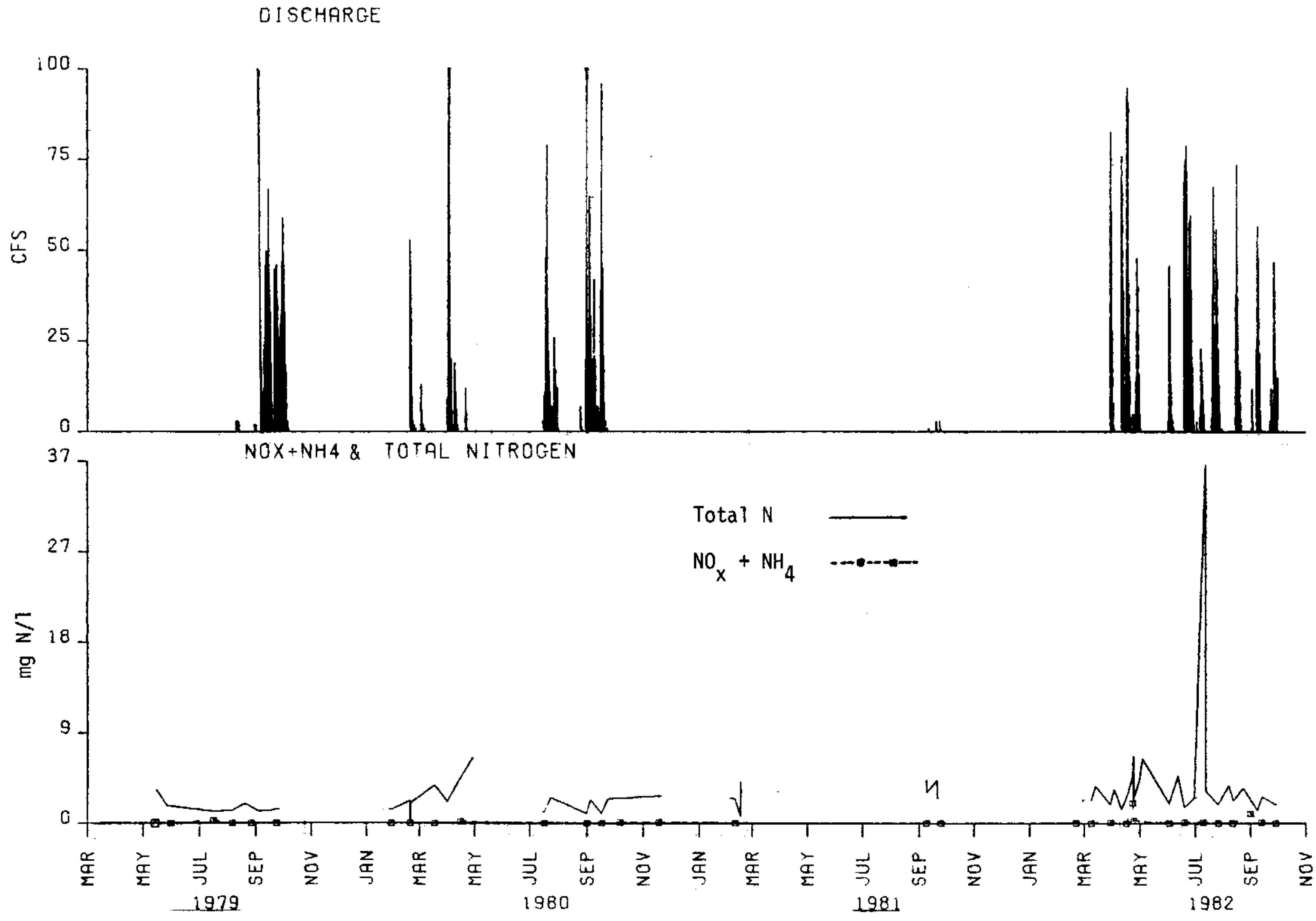


Figure V-43. Time Series Concentrations Ash Slough-West Watershed (1979-1982) Station 2.

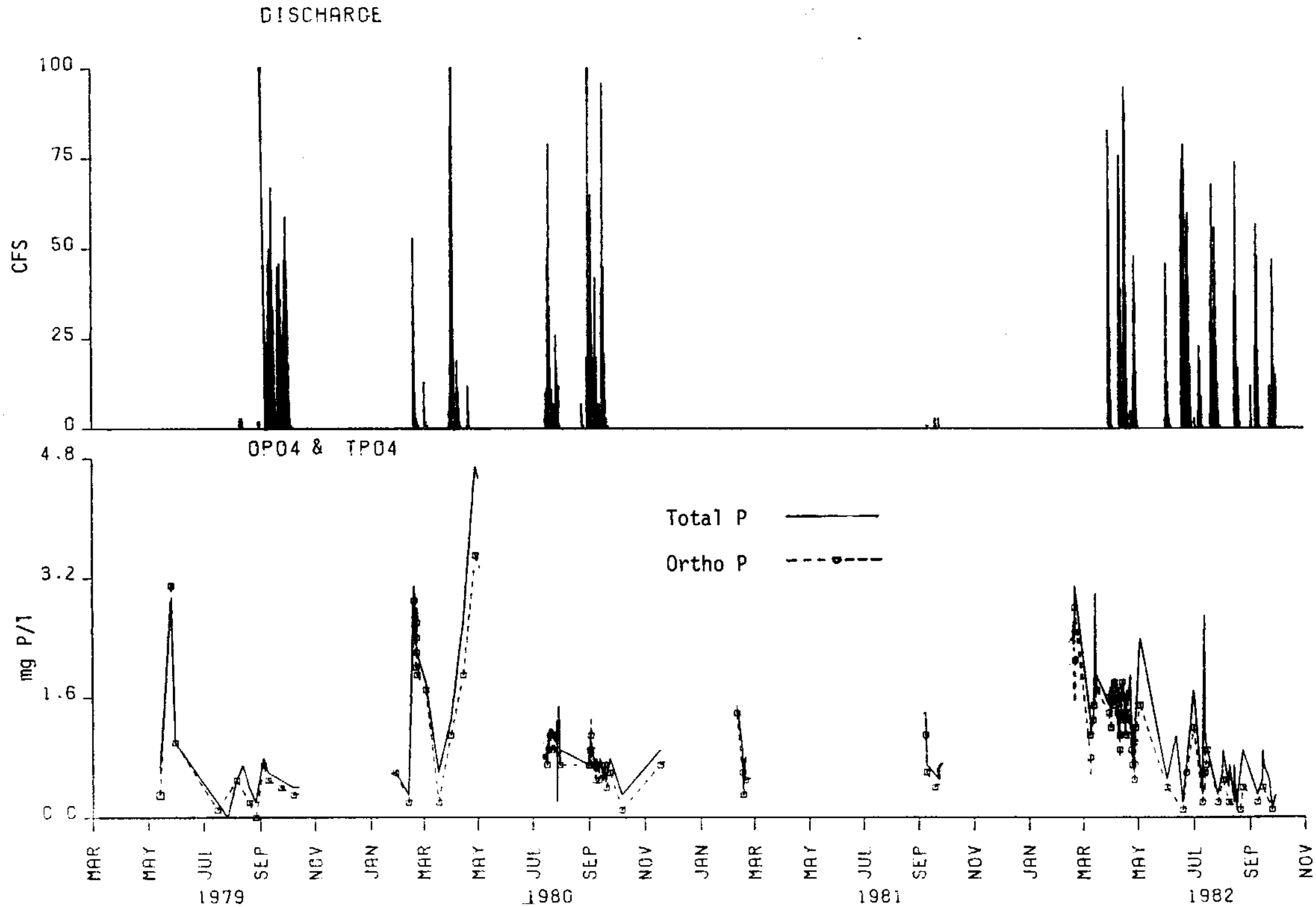


Figure V-44. Time Series Concentrations Ash Slough-West Watershed (1979-1982) Station 2.

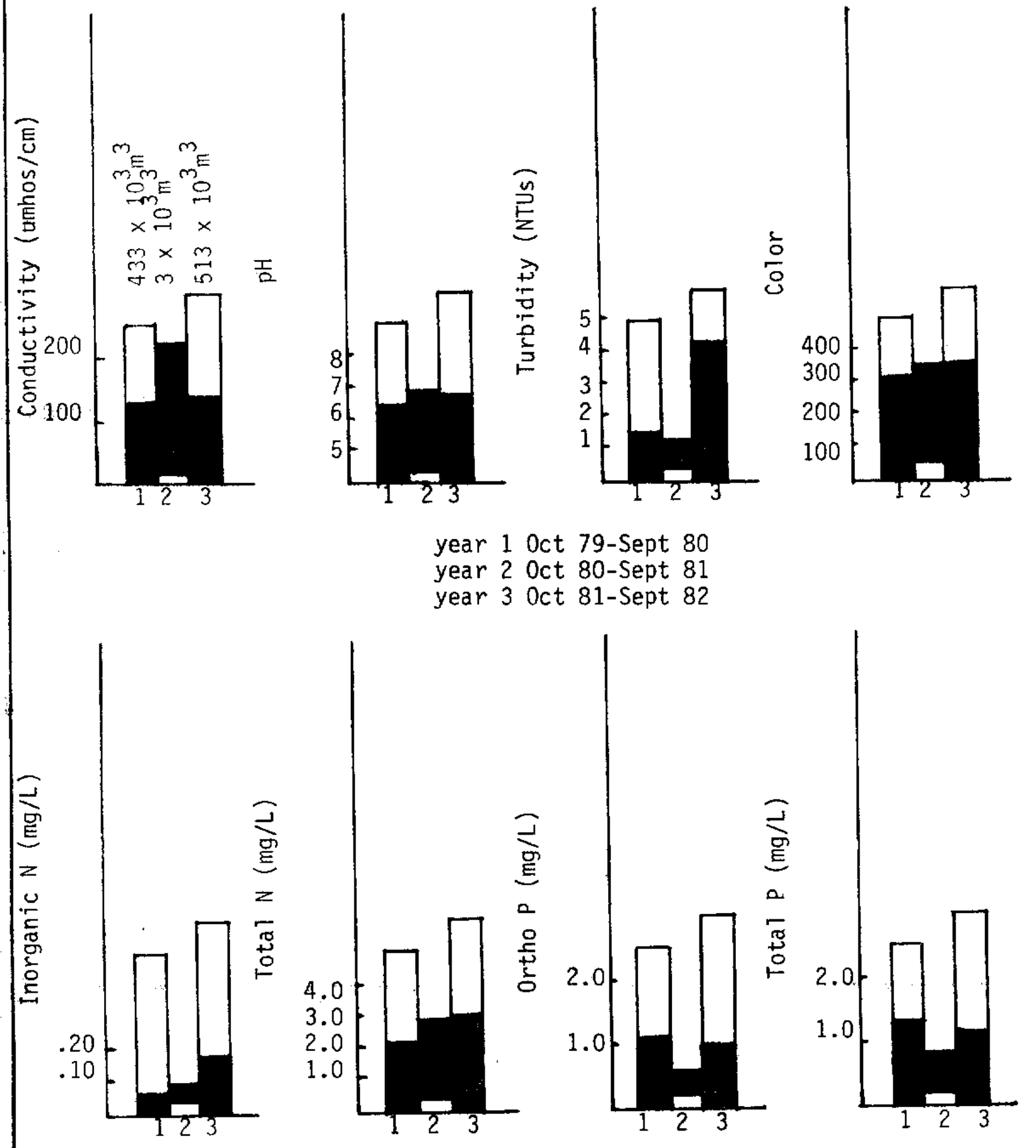


FIGURE V-45. ANNUAL MEAN CONCENTRATIONS AND TOTAL DISCHARGE AT ASH SLOUGH WEST (DITCHED PASTURE).

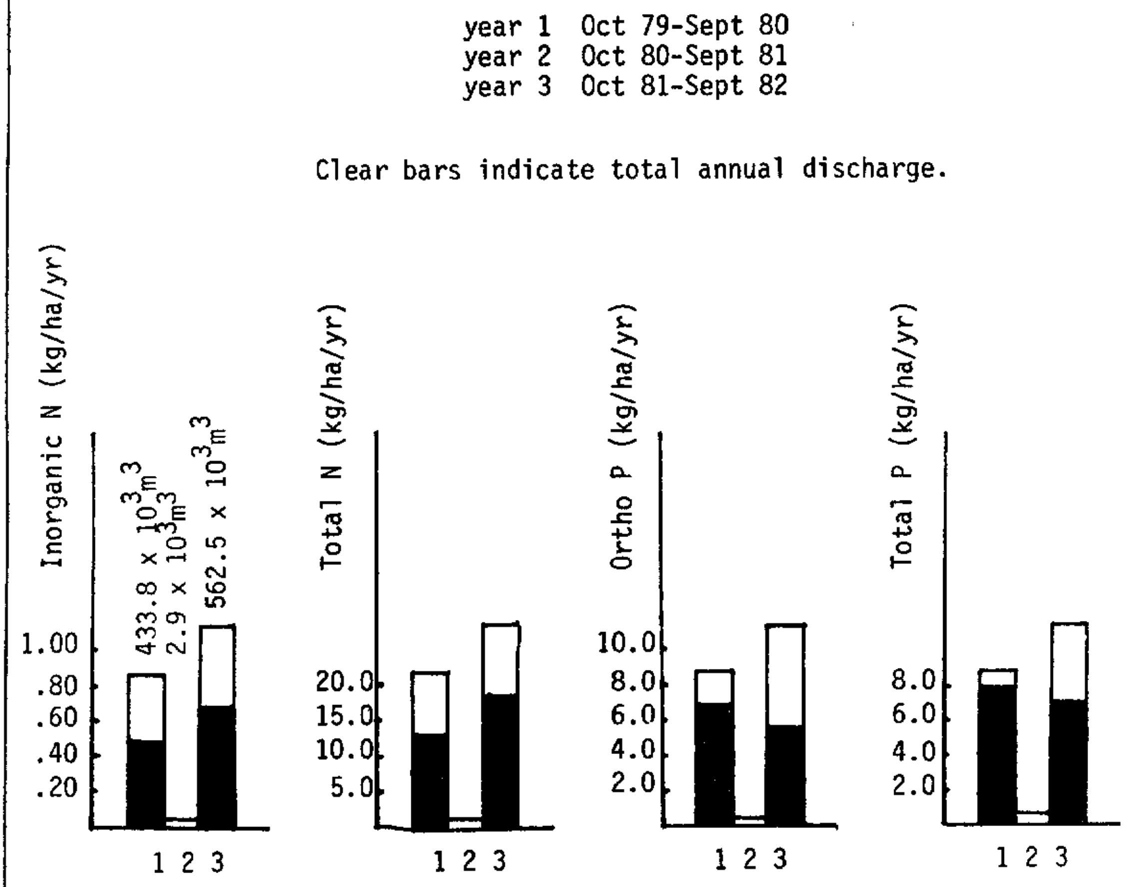


Figure V-46. ANNUAL MEAN NITROGEN AND PHOSPHORUS EXPORT RATES FROM ASH SLOUGH-WEST (DITCHED PASTURE) loads on the watershed became completely washed out. Subsequent to that period additional flow carried little or no P and the annual P export rate approached its maximum, thus becoming more constant. Given the time series concentration data discussed in the preceding paragraphs, this could be argued to be true in the present case.

SEZ DAIRY

Dairy activity is the most intensive agricultural land use in the Kissimmee River and Taylor Creek/Nubbin Slough basins. It has been identified by Allen et. al (1976), Stewart et. al. (1978), Federico (1977), and Ritter and Allen (1982) as the primary contributor of nutrients (primarily phosphorus) to the natural surface waters of the above referenced basins.

The SEZ Dairy just northwest of Okeechobee was considered to be typical of a moderately well managed dairy operation for the area. It had the advantages of being relatively isolated hydrologically as it is surrounded on three sides by a common perimeter drainage ditch and on the fourth by a highway crown. The land surface area is divided into 138 acres (56 ha) of holding and staging pasture for the milking herd, 536 acres (217 ha) of pasture utilized for hay and grazing of heifers and other cattle, approximately 5 acres (2 ha) for the lagoon barnwater waste treatment system, and the remainder of the 718 acres (291 ha) site is occupied by the milking barn, buildings, roads, or miscellaneously used land.

In addition to being the most intensive land use, nutrient loads on the watershed surface were contributed by the largest number of sources. There are three main sources of nutrient input on the land surface at the SEZ Dairy. There are: (i) atmospheric input (nutrients in rainfall), (ii) animal input from feces deposited on the ground surface of the holding and grazing pastures, (this fecal material is largely the remains of feed and supplements supplied to the animals from sources external to the dairy), and (iii) chemical fertilizer loads applied to the haying and grazing areas on an annual basis. During rainfall events of sufficient duration and intensity to generate runoff, either by overland flow or shallow lateral subsurface movement, water ultimately runs or seeps into the perimeter ditches. Nutrients deposited on the ground surface by these sources were transported via this runoff or seepage and monitored in the effluent leaving the dairy. A fourth significant source of nutrients in the dairy discharges was waste treatment lagoon effluent that was intermittently released from the lagoon system into the north perimeter ditch.

Given the existence of only one discharge outfall from the site, contributions from each of the phases of the dairy activity to the quality of the measured discharge are not discernible. It was assumed that mixing, nutrient transformation, and uptake (or release) occurred in the perimeter ditch during the time of transport to the site outfall. While unable to determine the ultimate fate of any specific unit of nutrient mass deposited on the dairy, enough monitoring stations were established on the site to estimate general characteristics of contributions from each source. An estimate was made of the amount of contribution from the waste treatment lagoon system to the overall discharge as compared to the integrated net contribution of nutrients from the other sources on the land surface.

The following discussion of the dairy operation will first evaluate the impact of the overall operation on the quality of water at the sites outfall. Subsequent to this, an evaluation of the relative magnitude of each of the contributing sources of nutrients will be discussed.

SEZ Dairy Site Outfall - Time Series Data

Time series water quality data and discharge for the period of record from April 1979 through October 1982 are depicted in Figures V-47 through V-50. For the physical parameters (color, pH, turbidity, and conductivity), it appears in each case that there is a certain baseline concentration that each parameter rarely, if ever, drops below. Each parameter is characterized by a succession of concentration peaks (or spikes) of various magnitude throughout the study. In the case of pH, the range of variation for minimum and maximum values was between about 6.5 and 8.0. The maximum peaks and valleys are of relatively constant magnitude and visually appear to be rather evenly distributed about the mean.

Conductivity, on the other hand, is characterized by a series of distinct sharp peaks, intermittently spaced. If one compares the conductivity peaks with observed dates of significant discharge from the lagoon system, one notices that in almost every case discharge from the lagoon system resulted in an increase in conductivity at Station 1. During the interim periods conductivity rapidly dropped to antecedent lower levels. The peaks, however, vary such that the magnitude of the peak does not necessarily correlate positively with the magnitude of the discharge event. In fact, in many cases, an inverse correlation appears to be the rule. That is, lesser magnitude discharge events are accompanied by greater peaks in concentrations. This is probably a reflection of the relative magnitude of the primary

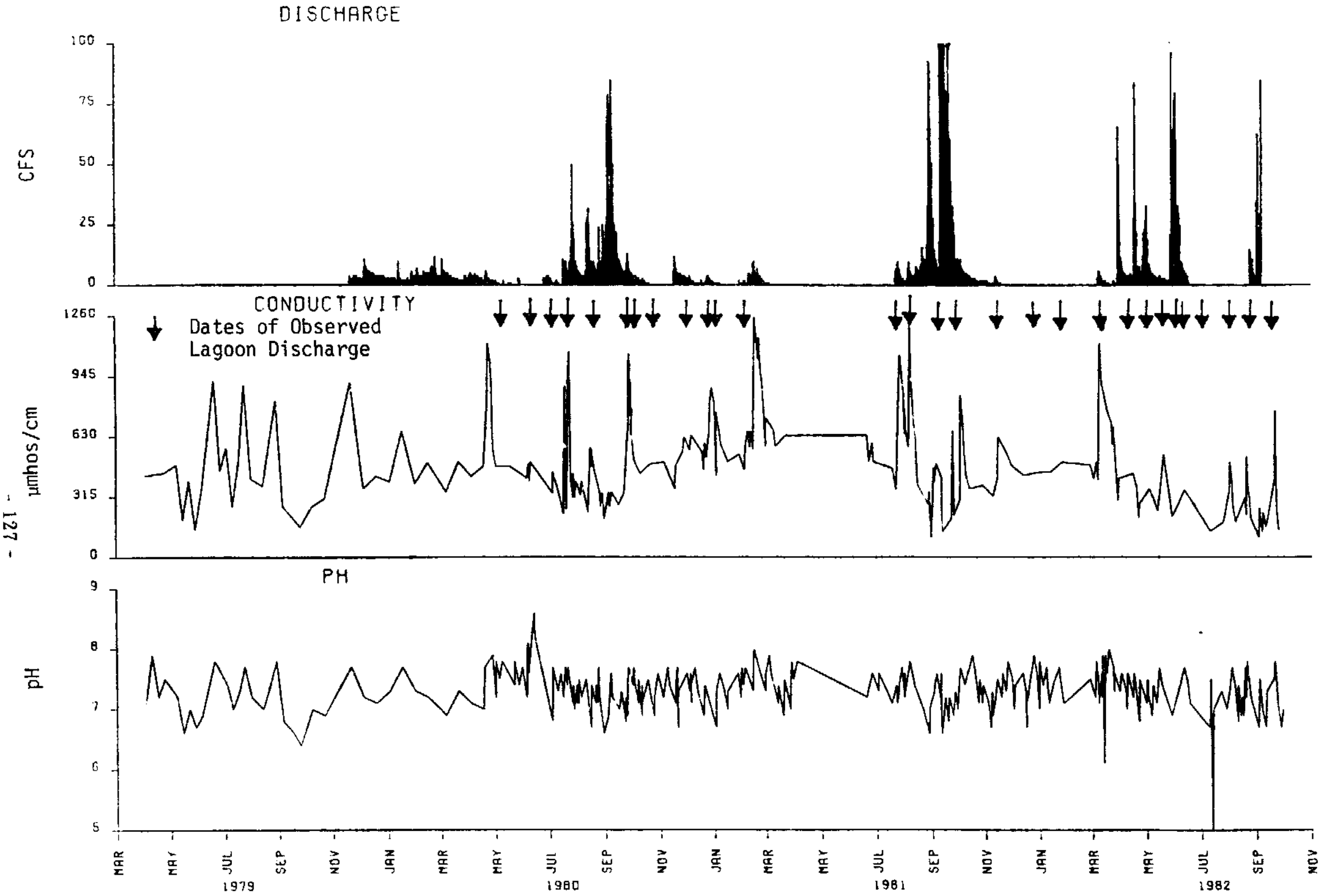


Figure V-47. Time Series Concentrations SEZ Dairy (1979-1982) Station 1.

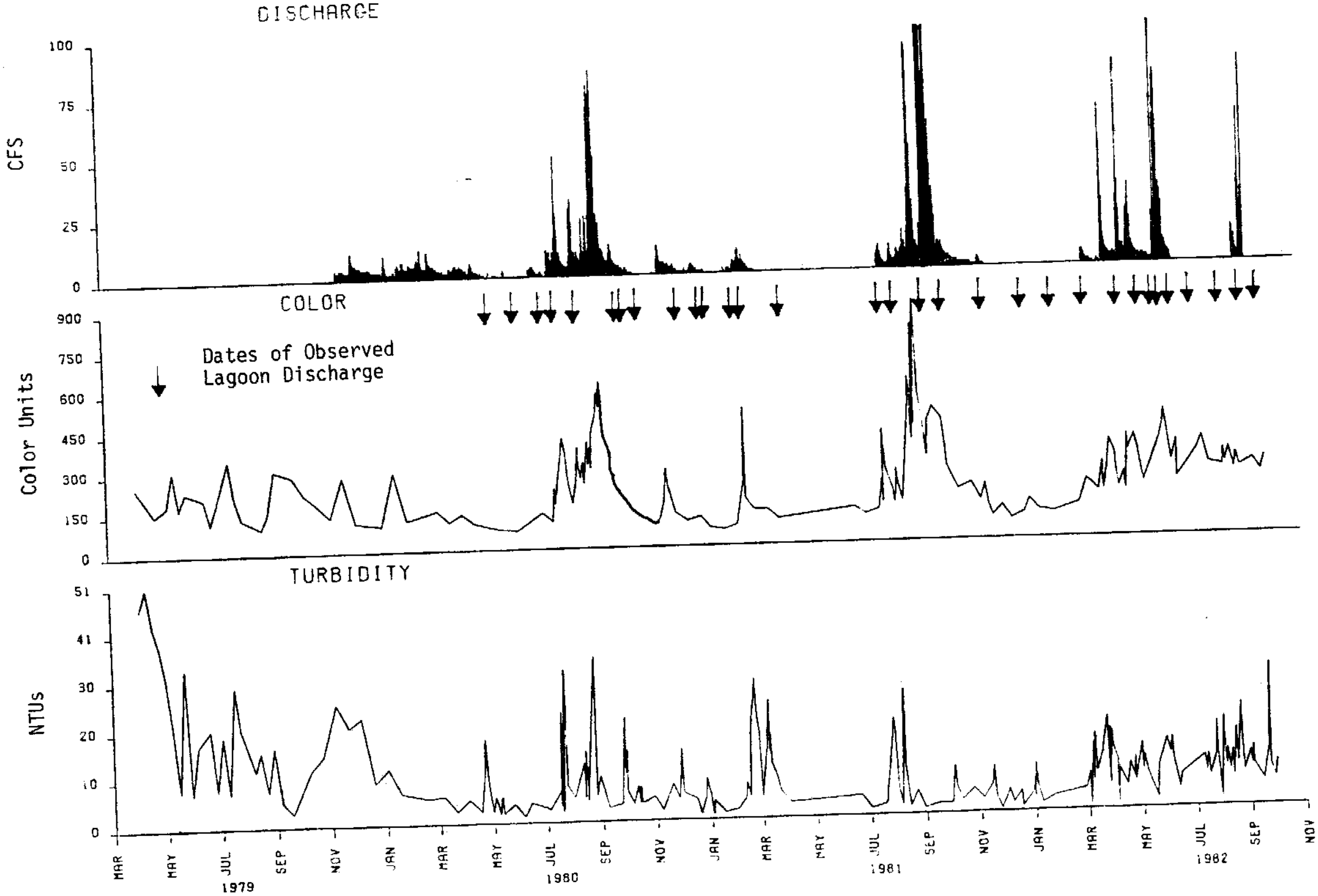


Figure V-48. Time Series Concentrations SEZ Dairy (1979-1982) Station 1.

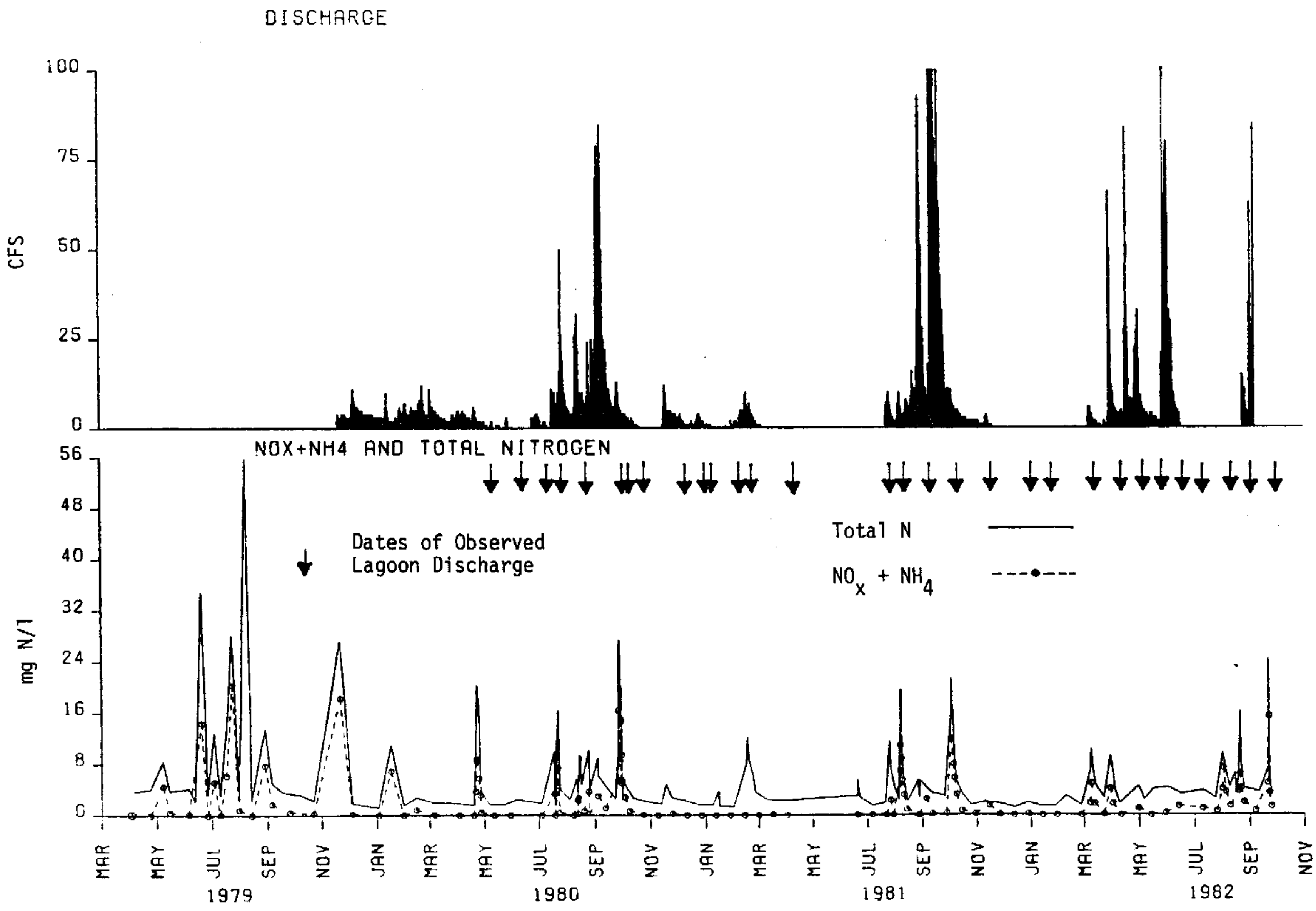


Figure V-49. Time Series Concentrations SEZ Dairy (1979-1982) Station 1.

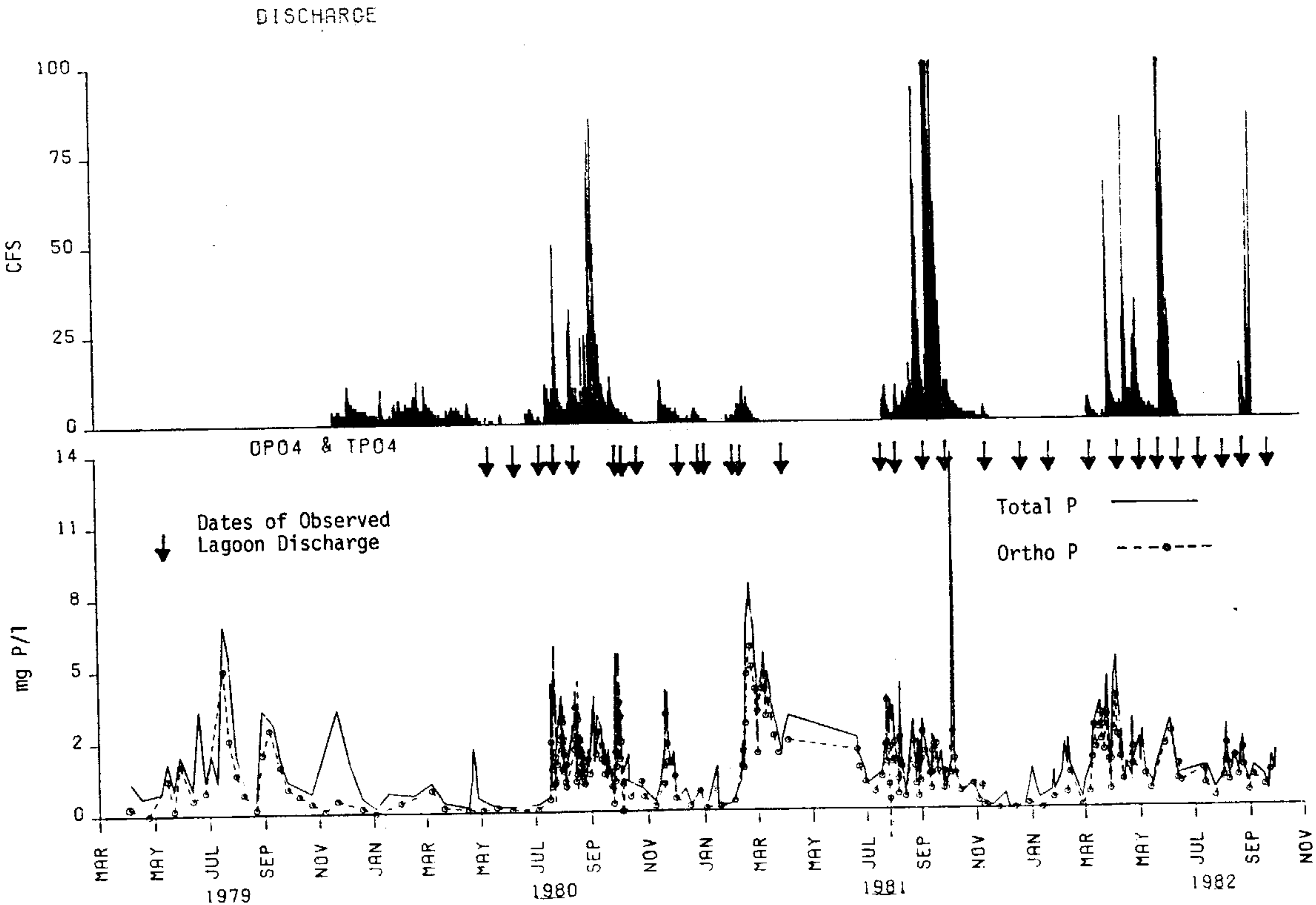


Figure V-50. Time Series Concentrations SEZ Dairy (1979-1982) Station 1.

source of the water being discharged at the outfall at the time. The major component of larger discharge events is usually surface runoff from pastures. When wastewater treatment system discharge occurs n conjunction with these large events, the lagoon water (characterized by higher conductivity) is mixed with surface runoff (from pastures) collecting in the perimeter ditch and is thus diluted. Discharge events where lagoon discharge is the primary source (the lesser events where surface runoff or shallow subsurface flow is nonexistent or minimal) are characterized by high conductivity of the contributing source.

Color and turbidity peaks also seem to correlate with periods of discharge at Station 1. Magnitudes of these peaks appear to be directly related to the magnitude of the runoff/discharge event. These parameters seem to respond to the total surface runoff/discharge events and appear to be rather insensitive to discharge from the waste treatment lagoons.

Background concentrations of total N remain at roughly 3 - 4 ppm. The majority of the total N concentration occurs as particulate organic material. Baseline dissolved inorganic N concentrations are low to non-detectable. During significant discharge events, N concentrations peak dramatically and sharply. The dissolved inorganic N component becomes the major constituent of the total N load during these times. These peaks can reach 30 ppm or greater for brief periods. They also tend to correlate with periods of intense surface runoff rather than those periods of observed wastewater treatment lagoon discharge. This suggests dissolved N load from the land surface is the major contributor.

Of the monitored parameters, phosphorus concentrations exhibit the most variation in magnitude of concentration and periodicity of peaks and valleys. The sensitivity of P concentrations to events on the contributing watershed began to show up vividly when the resolution of the sampling interval was increased from weekly to daily. P concentrations at the outfall seemed to respond to each discharge event whether it was surface runoff, lagoon discharge, or combinations of the two. Typical baseline concentrations were comparatively low (less than 0.1 ppm). During any period when water from either surface runoff or lagoon discharge was present, the P concentrations increased dramatically to 3-5 ppm and were, in some cases, significantly higher. The dissolved (ortho) component of the total P load was by far the major constituent comprising over 70 percent in almost all cases. The response of P concentrations to any movement of water regardless of its source (i.e. surface runoff and lagoon discharge) suggest strongly that all aspects of the dairy operation (wastewater treatment lagoons, holding pastures, and hayfield operations) are significant contributors.

It is of some interest to note that maximum concentrations of physical and chemical parameters noted at Station 1 are similar in magnitude to typical long-term concentrations of these parameters in the discharge from the wastewater treatment lagoons (Station 4).

Annual mean concentrations of each parameter and total discharge are plotted in Figure V-51. There are no distinct patterns of increasing or decreasing mean concentration with increasing discharge. This lack of correlation demonstrates the complex nature of the interactions and relative magnitude of each source of the water being discharged at Station 1 (i.e. dilution, mixing, etc., of different sources each with different chemical load characteristics).

SEZ Dairy Loading/Export

Once again there are three main sources of nutrient loads being contributed in the SEZ Dairy watershed. These and a fourth, the waste treatment lagoon system discharge, contribute to the quality of effluent being discharged from the site into Wolf Creek.

Estimates have been made of annual nutrient mass loadings on the watershed attributable to rainfall, cattle droppings, and fertilizer applications. Nutrient mass discharge from the lagoons was also calculated based on estimates of discharge and direct water quality measurements.

Fertilizer application on the hay and grazing pastures was estimated based on information provided by the landowner who routinely applies 300 pounds per acre per year of a 16/8/4 or similar N/P/K formulation during the spring (April or May). N and P fertilizer application was assumed to be predominantly in the inorganic form and was used as such in calculation of both inorganic and total nutrient loads.

Animal feces deposited on the pastures constitutes a significant P load. This is due to the fact that prepared dairy rations contain a substantial amount of added P (roughly 0.5 lb per hundred, or .5 percent). This is required for continued optimum health and milk production of the dairy herd. Each milking animal is fed approximately 40 pounds of the prepared feed mixture daily. The average milking animal thus ingests roughly 0.2 lbs of P in basic daily

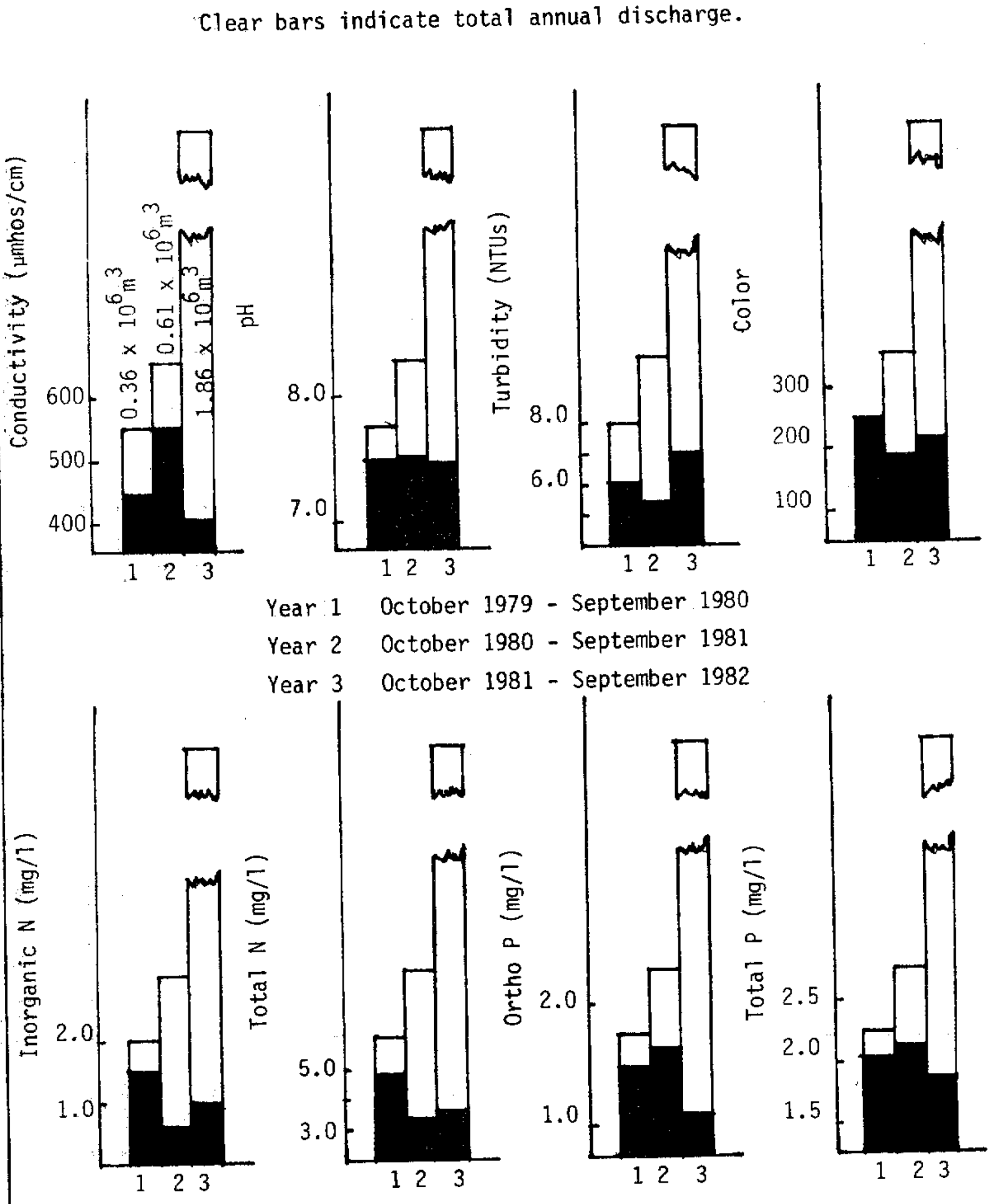


Figure V-51. Annual Mean Concentrations and Total Discharge at SEZ Dairy.

rations. Additional P is often added in other food and vitamin supplements. Dairy nutritionists (Barney Harris, University of Florida - personal communication) state that digestive P uptake efficiency by the animal amounts to roughly 50 - 55 percent. Given the assumption that this is the case at SEZ Dairy, then roughly 0.1 pound of P per animal per day ends up passing through the alimentary system and becomes deposited in the milking barn or on the pasture. Since each milking animal spends about one hour per day in the milking barn, it was assumed that 23//24 or .958 of the .1 lb P/animal day ended up on the pasture, the rest was assumed to most likely reach the waste treatment lagoons. Ignoring the fecal material reaching the lagoons, approximately 1430 pounds (650 kg) a month of P would likely be contributed in cattle feces to the SEZ Dairy watershed. This is probably a conservative estimate as it is calculated based on the average number of 500 milking animals only. In reality, non-milkers such as heifers and dry cows are fed portions of P enriched dairy rations but in lesser amounts. The total P load from feces would most likely be greater if these additional inputs could accurately be added in. P deposited in feces was assumed to occur predominantly in the dissolved ortho form.

Table V-3 provides a breakdown of the estimated relative percent contribution of each facet of the dairy operation to the total load onto the watershed.

Somewhat surprisingly the measured contributions from the waste treatment lagoon system are a rather small portion of the estimated total load of N and P. Fertilizer and fecal sources appear to be the primary contributors of the P loads.

Export rates from the SEZ Dairy as measured at the outfall site (station 1) were usually the highest of any observed among the five study sites. Annual uptake of N and P, as measured by the difference between the estimated nutrient loads on the watershed and measured nutrient loads leaving with the discharge, ranged from 96 to 99.5 percent for N species and 78 to 93 percent for P species. This suggests that improved pasture watersheds in the Kissimmee River basin have a remarkably high assimilative capacity for N and P but at such high loading levels assimilative capacity becomes overtaxed.

Export rates in kg/ha/yr are depicted in Figure V-52. Annual N export rates do not appear to directly correlate with measured annual discharge, while P export rates on the other hand, do seem to increase with increasing runoff and discharge.

UPLAND DEMONSTRATION PROJECT SITES LAND USE/WATER QUALITY COMPARISONS

Evaluation of nutrient contributions to receiving waters via non-point sources in relation to various land uses has been the subject of reviews and studies by Loehr (1974), Omernik (1976, 1977), and Asmussen, et. al. (1979).

In Florida such studies have been conducted by Hortenstine and Forbes (1972), Wanielista, et. al. (1977), and CH2M Hill (1978). Specific investigations in the Kissimmee River and Taylor Creek basins were conducted by Allen, et. al. (1975), Huber, et. al. (1976), and Federico (1977).

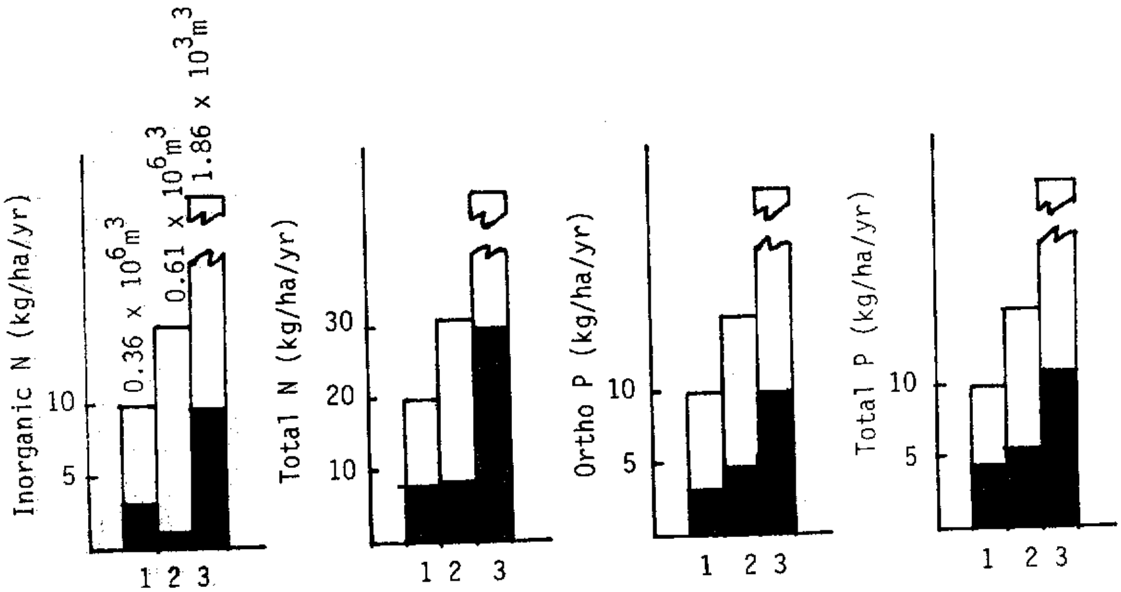
In most parts of the country, nutrient movement in runoff has been found to be predominantly associated with sediment transport. Studies have also been conducted to evaluate the fate of nutrients and water quality impacts with fertilizer application

TABLE V-3. MEAN PERCENT CONTRIBUTION OF NUTRIENT LOADS TO THE SEZ DAIRY WATERSHED

	Rainfall	Fertilizer	Feces	Lagoons	Total
Dissolved Inorganic N	3.1	95.5	*	1.4	100
Total N	6.17	90.7	*	2.6	100
Ortho P	1.4	45.0	55.5	1.4	100
Total P	2.41	40.05	54.0	3.3	100

* No estimate available - this source was not considered in computing total loads on the watershed.

Year 1 October 1979 - September 1980
Year 2 October 1980 - September 1981
Year 3 October 1981 - September 1982



Clear bars indicate total annual discharge.

Figure V-52. Annual Mean Nitrogen and Phosphorus Export Rates from SEZ Dairy.

Results of such a study in Michigan indicated that 70 to 90 percent of the N and 90 to 98 percent of the P were associated with sediments in runoff (Hubbard, et. al., 1982). Nutrient loss via sediment transport accounted for up to 96 percent of the total losses of P in a Minnesota study (Burwell, et. al., 1975). The amount of nutrient loss was found by Sharpley, et. al. (1981) to be directly related to the amount of vegetative cover. Less cover resulted in more erosion. Their studies on cropped and grassed southern plains watersheds in Oklahoma demonstrated a linear inverse relationship between soluble P concentrations and sediment concentration in runoff.

Greatest P losses were associated with the highest sediment loads in a study of impacts of various agricultural land uses in Wisconsin (Wendt and Corey, 1980). Owens, et. al. (1983) reported low N transport from study watersheds in Ohio, presumably due to low soil loss.

Several investigations have been conducted in attempts to determine the fate and water quality impacts of nutrients associated with fertilizer application. According to Loehr (1974) only 5 to 10 percent of P applied as fertilizer is taken up by the following crop. Owens (1983) reported N concentrations and transport in runoff from an area of high fertility (224 Kg N/ha-yr) exceeded N concentrations and transport in runoff from a medium fertility (56 Kg N/ha-yr) plot. Johnston, et. al. (1965) found that the tile drain effluent from irrigated farm land had highest levels of N and P losses during the first irrigation period following fertilizer application. Subsequent irrigation periods produced a tile drain effluent with less nutrient load. This phenomenon was especially noticeable for N. P losses were less as phosphorus seemed more apt to remain fixed in the soil. Hortenstine and Forbes (1972) in a study of various fertilizer application rates on Everglades muck and peat type soils in the vicinity of L ke Apopka, Florida, reported that inorganic P concentrations in soil moisture samples increased at the highest fertilizer application rates.

General land use appears to be a universal criteria for predicting at least relative differences in quality of non-point source runoff. Runoff reflects the sum total of all the integrated effects from factors that characterize those uses (i.e. soil type, amount of disturbance, vegetative cover, fertilizer application, harvesting, livestock density, impermeable surface, amount of flooding/drainage, etc.). In an evaluation of the influence of land use on stream nutrient levels east of the Mississippi River, Omernik (1976, 1977) found that runoff from the least intense uses (i.e. forest area) had lowest concentrations of both N and P. These areas also contributed the least loads of these nutrients to the receiving waters. Urban and agricultural areas were found to export the highest loads of N and P. Concentrations of N and P were far higher in runoff from agricultural areas, but presumably the amount of impermeable surface in urban areas resulted in a more complete flushing of nutrients present as more runoff can be generated from similar intensity storms. Some total N and P export rates with given land uses as reported in the literature are presented in Table V-4.

Huber, et. al. (1976) found that a relationship existed between concentration of nutrients in runoff from agricultural watersheds in the Kissimmee River basin and the amount of drainage density in miles of ditches per unit surface area.

As noted previously, the subject study area of the Upland Demonstration Project is characteristically flat with predominantly sandy soils. Erosion and sediment transport are minimal and compared to other areas of the country, extremely low. The upper layers of sand are porous and permeable with an available water capacity of less than 0.05 inches per inch of soil (McCollum and Pendleton, 1971). A relatively hard spodic layer exists roughly 30 to 48 inches below the surface. This serves as somewhat of an aquaclude and impedes the rate of downward percolation of water through the soil profile. As a result of this, when the soil becomes sufficiently saturated shallow groundwater apparently moves laterally as sub-surface flow until it enters intercepting canals, drainage ditches, or natural water courses. The lack of silt or clay sediment eliminates sediment sorption of nutrients and subsequent sediment load movement from the watershed. Instead N and P move principally as organic detrital material in sur ace runoff and in dissolved forms in either surface runoff or shallow sub-surface flow. Nitrogen export from the Upland D/R project watersheds occurs predominantly in the particulate organic form. A major percentage of P on the other hand (particularly on the most intensely loaded watersheds), appears to occur commonly in dissolved form.

The intensity of land uses on the Upland Demonstration Project watersheds can be arranged in a sequence from least to most intensive based on factors such as animals per unit area and annual estimated fertilizer loads applied to the land surface.

TABLE V-4. LITERATURE VALUES OF TOTAL N AND TOTAL P EXPORT RATES IN NON-POINT RUNOFF BY LAND USE (kg/ha/yr)

Location	Land Use	Total N Export	Total P Export	Source
Great Lakes Basin	Row Crops	32.5 - 36.4	15.7 - 20.6	Hubbard, et al, 1982
Ohio	Grazing	2.8 - 7.6		Owens, et al, 1983
Virginia Coastal Plain	Swamps and Wetlands	2.2	0.19	Butterfield, et al, 1980
Virginia Coastal Plain	Row Crops and Forest	0.26 - 0.55	2.7 - 3.4	Butterfield, et al, 1980
Virginia Coastal Plain	Swine Production	1.4	5.3	Butterfield, et al, 1980
Oklahoma	Pasture	1.73 - 9.20	0.20 - 4.90	Olness, et al, 1980
Florida	Pasture		>0.75	Allen, et al, 1976
Florida	Dairy		>6.10	Allen, et al, 1976
Minnesota	Prairie	0.8	0.1	Timmons and Holt, 1977
Great Lakes Basin	Cropland		0.68	Miller et al, 1982
Great Lakes Basin	Livestock		0.08	Miller, et al, 1982
Florida EAA	Sugarcane	27.1	0.67	CH_2M Hill, 1977
Florida EAA	Vegetable Farm	38.8	2.4	CH_2M Hill, 1977
Florida EAA	Cattle Ranch	12.3	0.6	CH_2M Hill, 1977
Florida	Urban	>5.6	2.6	Wanielista, et al, 1977
Florida	Suburban/Agricultural	>1.1	2.17	Wanielista, et al, 1977
Nationwide	Forest	3 - 13	0.03 - 0.9	In Loehr, 1974
Nationwide	Cropland	0.1 - 13	0.06 - 2.9	In Loehr, 1974
Nationwide	Urban	7 - 9	1.1 - 5.6	In Loehr, 1974
Minnesota	Hayfield (Solution)	4.10	0.66	Burwell, et al, 1975
Minnesota	Fallow Field (Solution)	3.43	0.19	Burwell, et al, 1975
Minnesota	Corn (Solution)	2.42	0.41	Burwell, et al, 1975

Using the first criteria, the watershed usage would be arranged from the least to most intense as follows:

Watershed	Cows/Acre
Wildcat Slough	0.05
Peavine Pasture	0.20
Armstrong Slough	0.20
Ash Slough	0.33
SEZ Dairy	1.63

Using the second criteria, the watershed usage would be arranged from the least to the most intense as follows:

Estimated Annual Loads

Watershed	KG/ha Total N	Kg/ha Total P
Wildcat Slough - East and West	13.5	0.8
Ash Slough - East	14.1	0.9
Armstrong Slough - South	58.9	11.5
Peavine Pasture	94.1	22.5
Armstrong Slough - North	199.5	21.3
Ash Slough - West	81.6	34.6
SEZ Dairy	264.0	52.9

Comparisons of N and P species export rates and flow-weighted concentrations from Upland Demonstration Project Watersheds are depicted in Figures V-53 through V-56. With these comparisons several trends become evident. First and most obvious

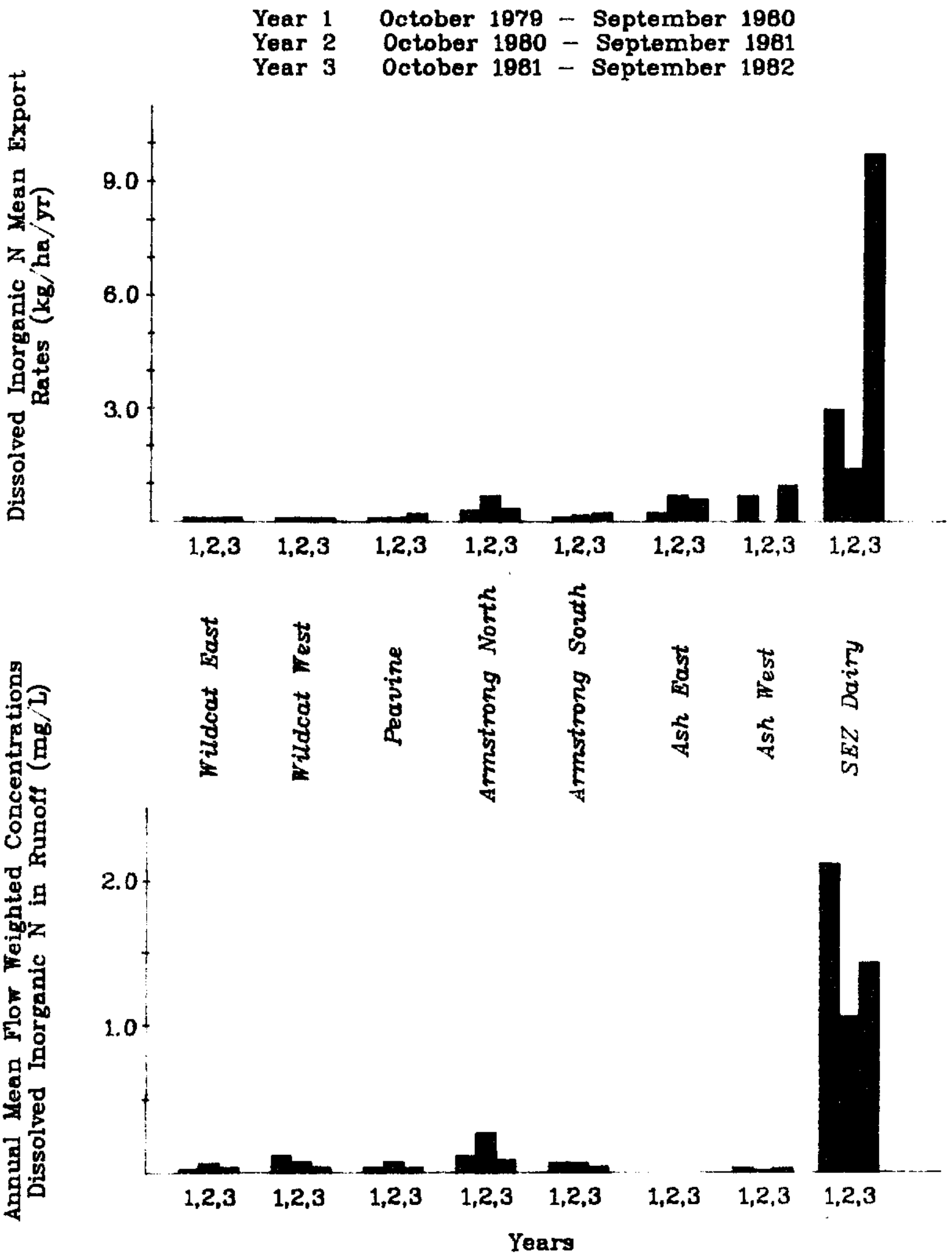


Figure V–53. Annual Export Rates and Mean Flow Weighted Concentrations of Dissolved Inorganic N in Runoff from Upland Demonstration Project Watersheds

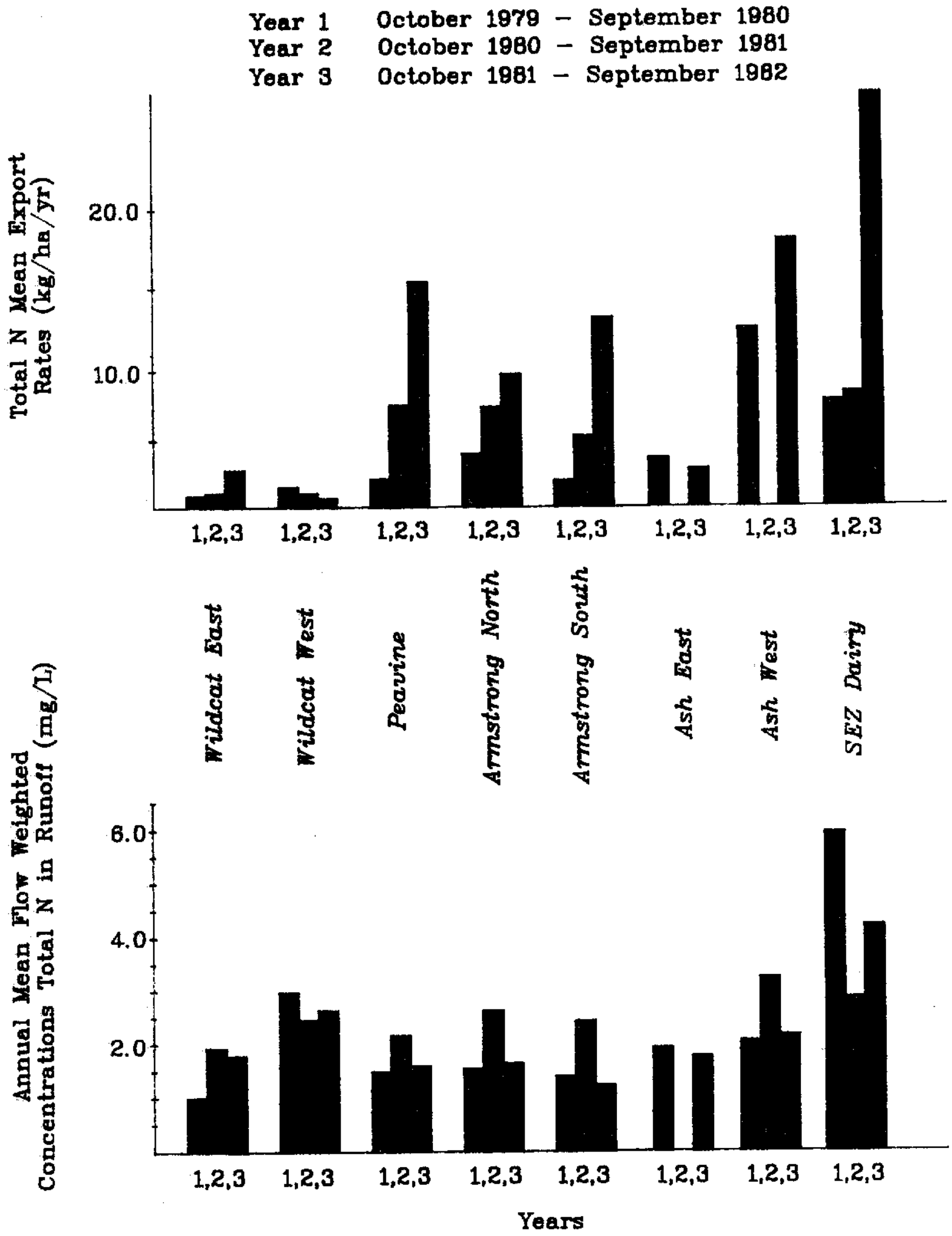


Figure V–54. Annual Export Rates and Mean Flow Weighted Concentrations of Total N in Runoff from Upland Demonstration Project Watersheds

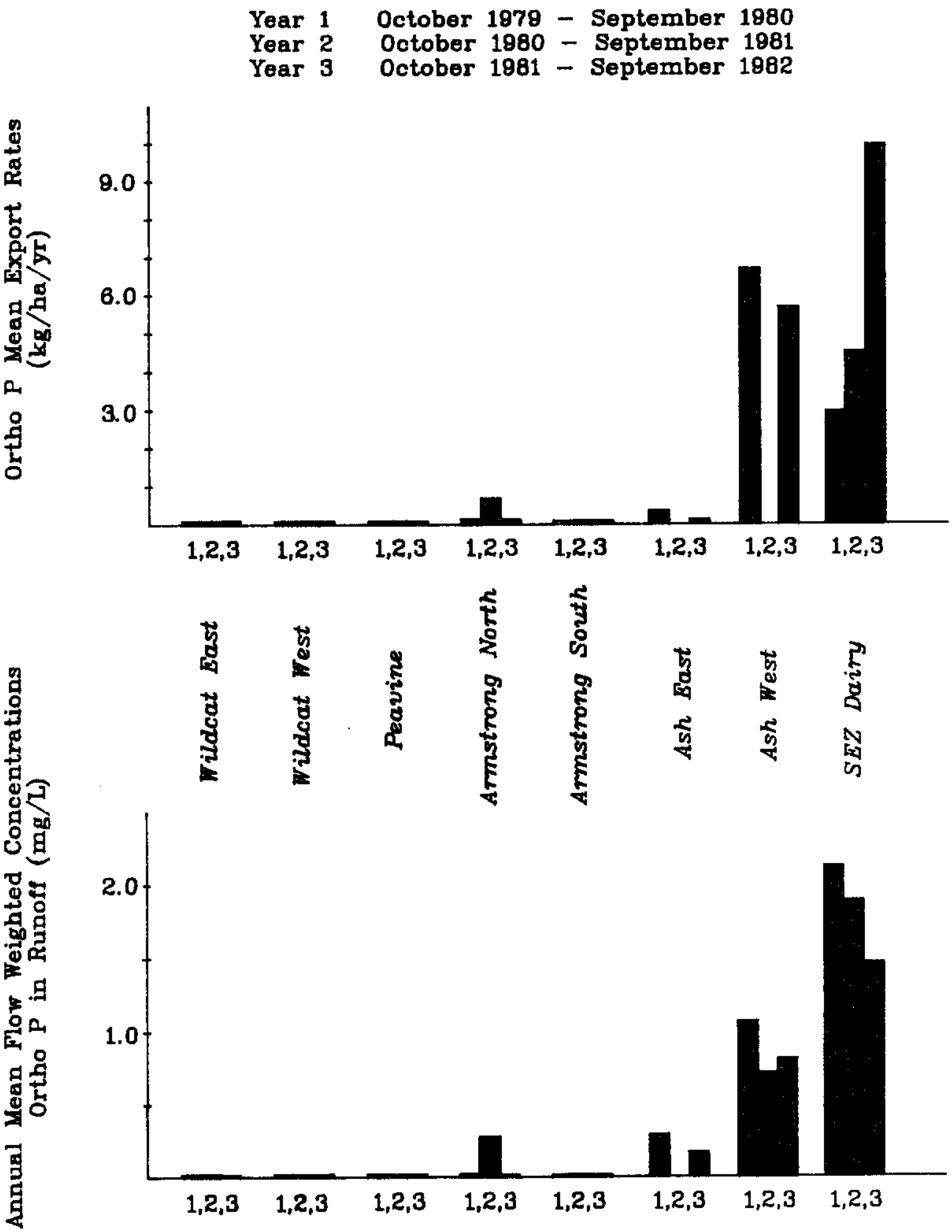


Figure V–55. Annual Export Rates and Mean Flow Weighted Concentrations of Ortho P in Runoff from Upland Demonstration Project Watersheds

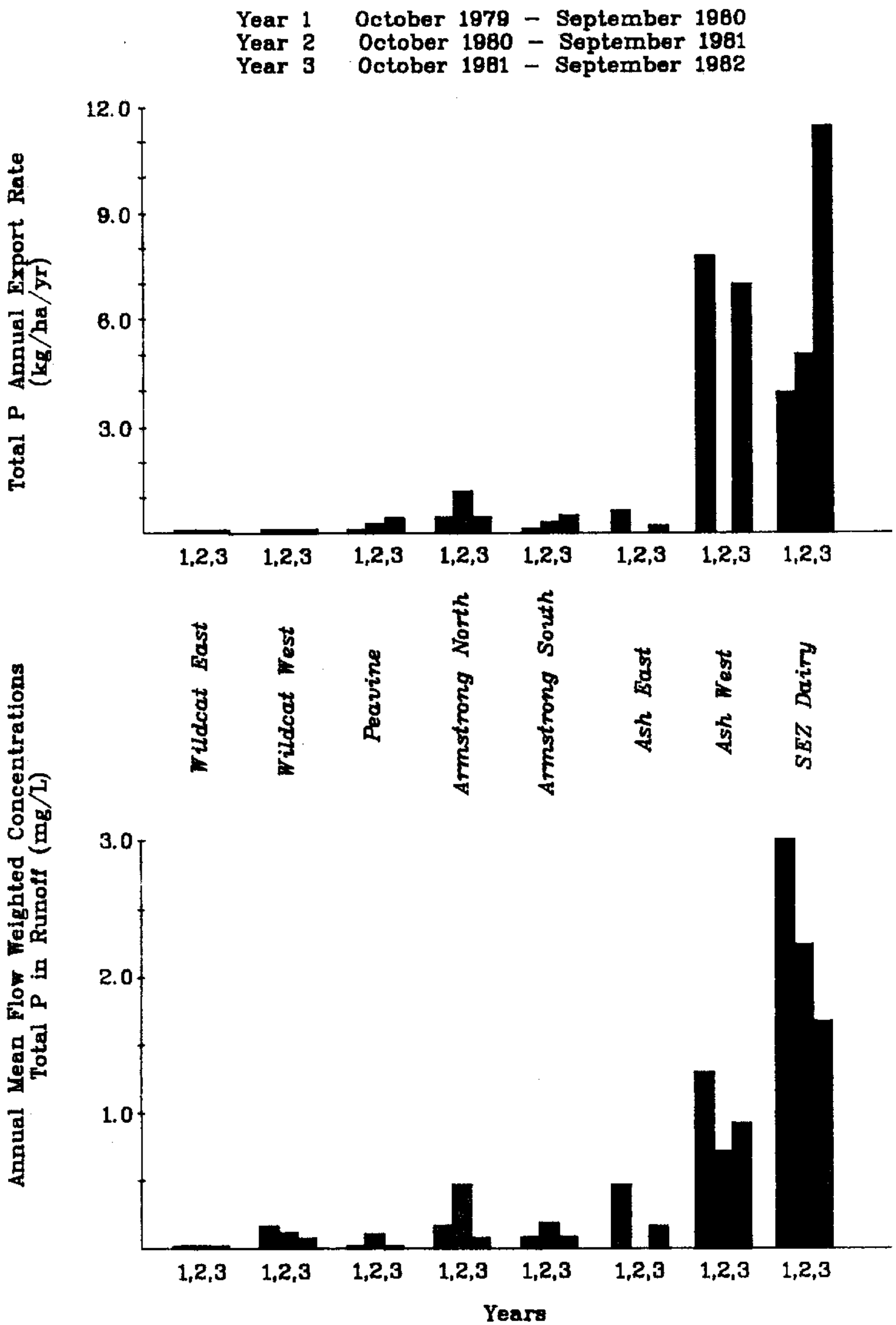


Figure V-56 Annual Export Rates and Mean Flow Weighted Concentrations of Total P in Runoff from Upland Demonstration Project Watersheds is that with each of these nutrient species, more intense land uses result in increased exports of nutrients from the watersheds. The impact of land use intensity on these watersheds appears to affect N species far less than P. While there are some obvious differences in flow-weighted concentrations, the difference between the worst and best quality runoff, defined as highest and lowest flow-weighted concentrations, is a factor of about 90.8 for total P and a factor of 209 for ortho P.

Quite obviously the differences in land use intensity as measured by nutrient loads on the watersheds had the most impact on P concentrations in runoff (ortho P in particular). Total P concentrations in the runoff appeared to be almost 24 times more sensitive to these land use practices than were total N concentrations.

Export rates from these watersheds responded to loading in a manner similar to the flow-weighted concentrations. Based on the differences between the greatest and least export rates for each species, total P appeared to be roughly 33 times more sensitive to increasing land use intensity than was total N.

Dissolved inorganic N and ortho P were the species that exhibited especially wide ranges in the maximum and minimum export rates. These appear to be the most sensitive components.

Comparing the estimated load on each watershed with the measured load out (in Kg/ha-yr), one finds that at the present loading rates each watershed serves as a rather efficient net nutrient sink. The efficiency begins to drop on those watersheds that are loaded most heavily (notably Ash Slough - west and SEZ Dairy), but even these perform quite well. Almost all of the dissolved inorganic N applied to these watersheds is either mineralized or assimilated into organic form. Even at SEZ Dairy, over 98 percent reduction of the estimated inorganic N load occurs.

All eight watersheds are less efficient absorbers of total N loads than would be expected based on the inorganic N load reductions, but still perform consistent reductions of about 87 to 94 percent. An exception is Armstrong Slough - north, which exhibits an estimated load reduction of total N of about 97 percent. A portion of this watershed is dedicated to citrus production which, by fertilizer application, is loaded with N at a rate much higher than that of surrounding improved pasture. N exports in surface runoff from this area, measured as 5.5 Km downstream, appear to be relatively insignificant indicating that it is either largely utilized by the citrus or is lost to the groundwater.

Figure V-57 depicts total N uptake rates versus estimated loading rates on the Upland Demonstration Project watersheds . The diagonal line drawn through the origin represents 100 percent uptake efficiency. In order to determine potential impact of land use on runoff quality, the two critical factors are the distance of the plotted points from the origin and the distance of the points from the diagonal 1:1 line representing 100 percent uptake. The further away the points are from this 1:1 diagonal, the more the impact on the receiving waters.

In the case of total N, all of the points representing the uptake versus loading rates on each watershed remain relatively close to the diagonal. Watersheds that are lightly loaded, such as Ash Slough-east and Wildcat Slough east and west (less than 20 Kg/ha-yr), are all grouped in one cluster near the origin.

The more heavily loaded watersheds (50-200 Kg/ha-yr), Armstrong-south and north, Ash-west, and Peavine, all fall slightly but similarly below the diagonal. This indicates that N loadings in this range impact surface water runoff quality slightly more than those of the previous group. Two of the three data points from SEZ Dairy (250 Kg/ha-yr) reflect uptake efficiencies similar to those observed at the Armstrong-Peavine watershed; however, the third falls significantly below the diagonal line. From these data one might speculate the 250 Kg/ha-yr loading of total N is near the maximum that these watersheds can consistently absorb before the uptake efficiencies drop and increases in concentrations in surface runoff occur. There is no data from this study to suggest the fate of this nitrogen, whether it is assimilated by vegetation, mineralized, or lost to groundwater. Studies by Sylvester and Seabloom (1963) in the Yakima River Valley in Washington found ten-fold increases in nitrates and three-fold incre ses in phosphorus in sub-surface return flow from irrigated, fertilized fields. Johnston, et. al. (1965) observed a large percentage of N loss from fertilized fields occurred in tile drainage effluent in a California study. Owens, et. al. (1983) found sub-surface flow to be the main pathway for N transport from fertilized grazing lands in Ohio.

Data collected at nine wells on the five Upland Demonstration Project sites (Goldstein, 1981) are depicted in Figure V-58. Mean total and dissolved inorganic N concentrations at groundwater monitoring stations are plotted against estimated average annual watershed total N loading rates. Ignoring the Armstrong Slough-north station, there is a consistent positive correlation of increasing total N concentrations in groundwater with increasing annual N loads

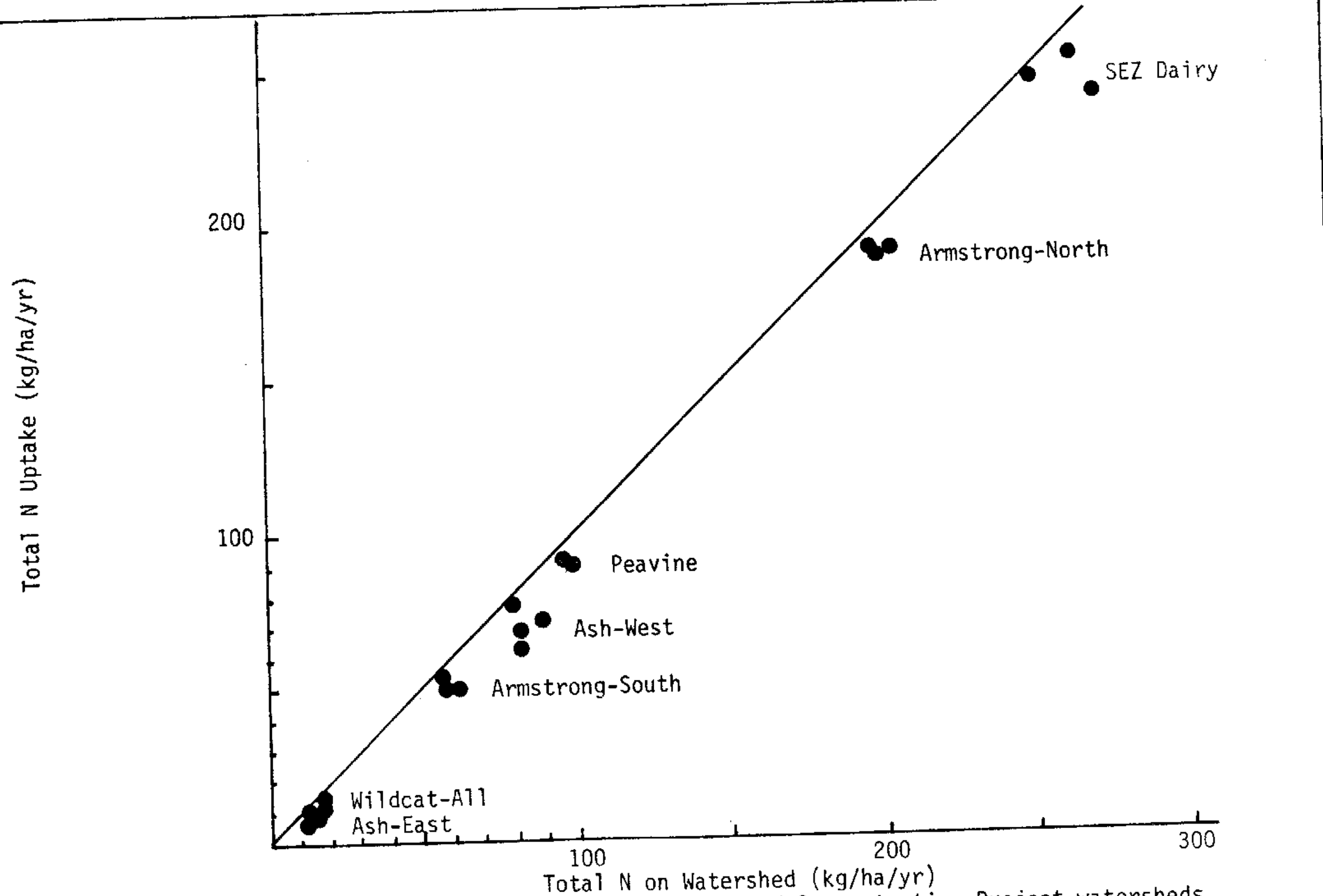


Figure V-57. Uptake versus loading rates for total N on Upland Demonstration Project watersheds.

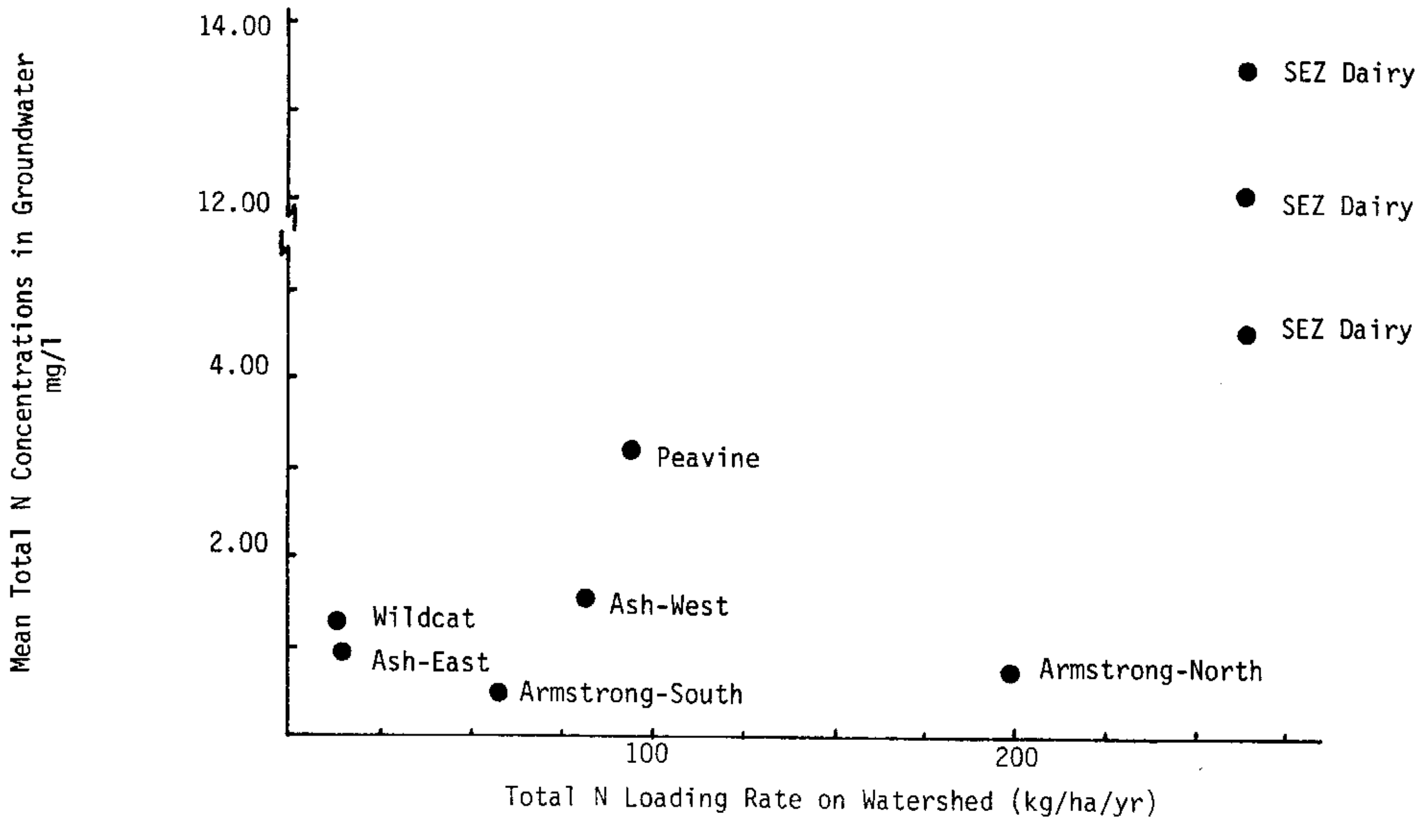


Figure V-58. Mean Total N Concentrations in Shallow Groundwater Versus Total N Loading Rates on Upland Demonstration Project Watersheds.

on the watershed. The Armstrong Slough-north data point is misleading as the annual total load on the watershed is biased by the high load application of N fertilizer on the portion of the watershed devoted to citrus. The groundwater monitoring station was some distance away at the edge of improved pasture and, as such, reflected N loadings in the vicinity which were more consistent with those on the Armstrong Slough-south watershed. Replotting the data using Armstrong Slough-south loading rates for the Armstrong-north well, the total N concentration d ta follows the expected pattern. The data for the three stations at SEZ Dairy form a vertical plot. This is an artifact of the use of mean annual watershed loading rates to describe three very different spots. In reality one intuitively knows that staging pastures are subject to heavier and more consistent loads than the haying pastures, and the lagoon is a place of intense concentration of nutrient materials, many continuously in solution, and as such, they are subject to move with the transport medium.

If one were to consider the station adjacent to the waste lagoon as a special case and omit it from calculations, and use the average of the mean concentrations at the other two dairy stations as representative of the "average" impact of this dairy land use on the total N in groundwater, the resulting data would reflect a linear relationship (Figure V-59) with an exceptionally good correlation coefficient ($r = 0.95$).

High dissolved inorganic N concentrations in groundwater adjacent to the SEZ Dairy waste lagoon again reflect the impact of this special case condition. Omitting this station from consideration and plotting mean inorganic N concentrations against watershed loading rates for inorganic N (Figure V-60) again results in a good correlation ($r = 0.86$). This scatter plot of the mean concentration data depicts all but the SEZ Dairy data points clustered in apparently random fashion at low concentration levels. When SEZ Dairy data is completely eliminated from consideration the remaining mean concentration values appear totally uncorrelated with land use intensity ($r = .064$). At loading rates of less that 100 Kg/ha-yr dissolved inorganic N appears to have no impact on the contentrations of that constituent in underlying groundwater. Loading rates in excess of 260 Kg/ha-yr do appear to have a very positive impact on groundwater quality, although caution must be exercised as this is based on only one data point. It appears then that there is some loss of N to groundwater where large loads are applied at the ground surface.

Total P uptake on the watershed versus loading rates (Figure V-61) resembles that of total N with the exception that loadings of the magnitudes noted at Ash Slough-west and SEZ Dairy significantly veered the curve away from the diagonal. Uptake efficiency of ortho and total P loads exceed 96-97 percent on all watersheds except those at Ash Slough and SEZ Dairy. Two of the three watersheds on these sites are P loaded at significantly greater rates than are the other study watersheds. Ash Slough-east is somewhat of an anomaly as it exhibits the poorest percentage of P uptake of any of the watersheds, yet it is estimated to be among the least heavily loaded. Ortho and total P uptake efficiencies are roughly 10 percent less at the Ash Slough-west and SEZ Dairy than at the other sites (with the exception of Ash Slough-east). Total P loading rates of less than 24 Kg/ha-yr on the watersheds seemed to have little or no impact. Loads at 34 Kg/ha-yr, however, resulted in a definite reduction in percentage of u take. It would seem logical to expect these curves to follow a classic Michaelis-Menten or similar model (Figure V-62), that is, uptake of nutrients would increase at some non-constant rate given increasing loads on the watershed. The rate of uptake would increase less than the concomittant increase in loading rate until such time as saturation of the soils occurs. At that time no additional uptake would occur and all additional loads would be discharged with the surface runoff or later at subsurface flow. Behavior of the N component would probably be somewhat more complicated as mineralization to elemental N (and subsequent volatilization) as well as loss to deeper groundwater would continue to contribute to some loss from the system as the theoretical saturation point was reached. Given a model of this type, and using this data obtained for N and P, one might be able to predict this level of saturation as well as what levels of application of loads the watersheds can assimilate before degradation of s rface water quality beyond an acceptable point occurs.

Unfortunately, impacts on receiving water quality seem to occur at loading levels far below the theoretical soil saturation. Indeed P exports from loading on agricultural operations of the magnitude observed at the Ash Slough-west and SEZ Dairy watersheds are significant enough to contribute to degradation of receiving water quality. Fortunately, if this or some similar model is a representation of reality, it could be used to evaluate what level of loading on a per unit area basis would result in potential nutrient exports such that a particular water body's maximum allowable load would not be exceeded. Agricultural practices could be permitted with nutrient export per unit surface area caps being

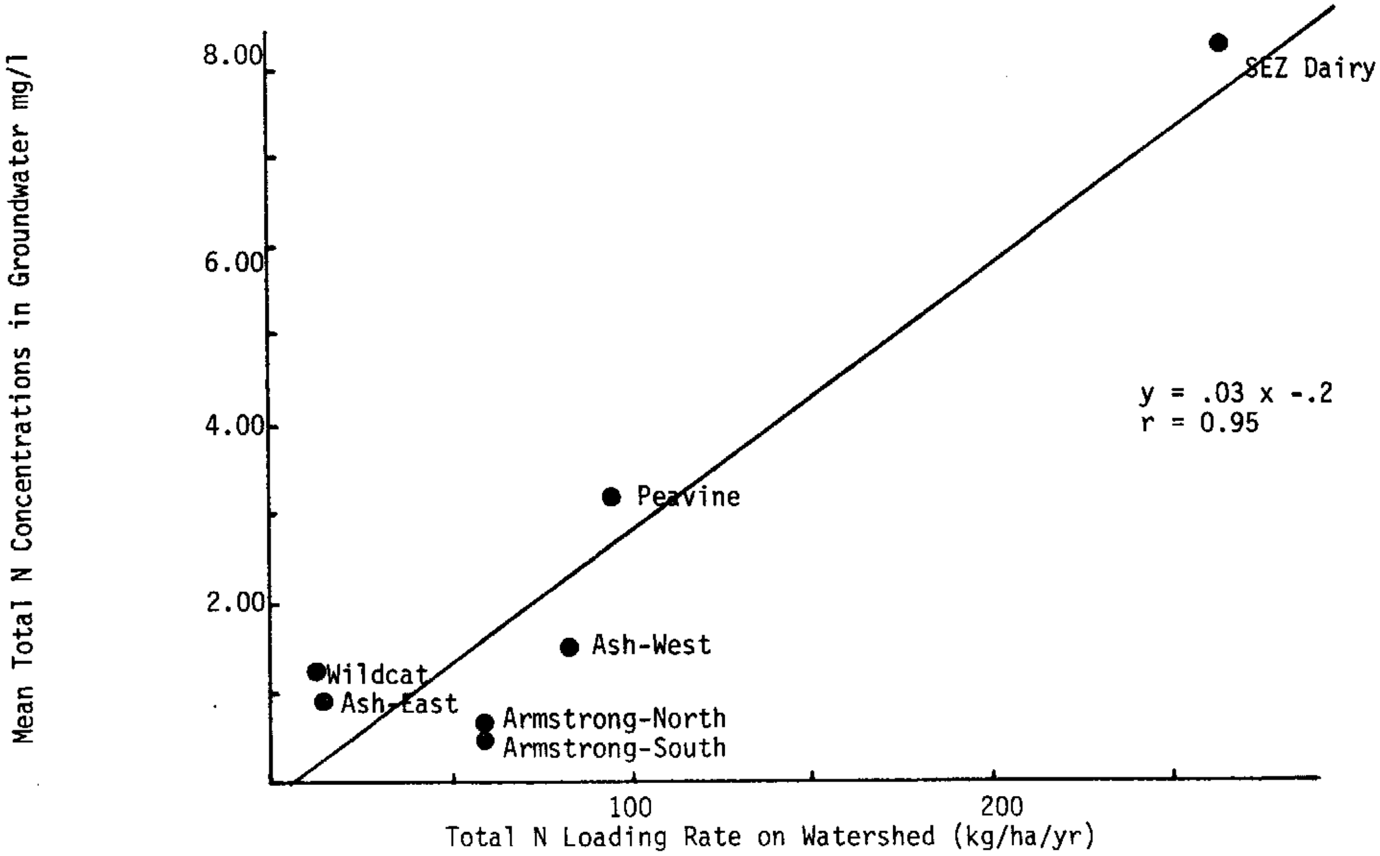


Figure V-59. Mean total nitrogen concentrations in shallow groundwater verses total nitrogen loading rates on Upland Demonstration Project watersheds.

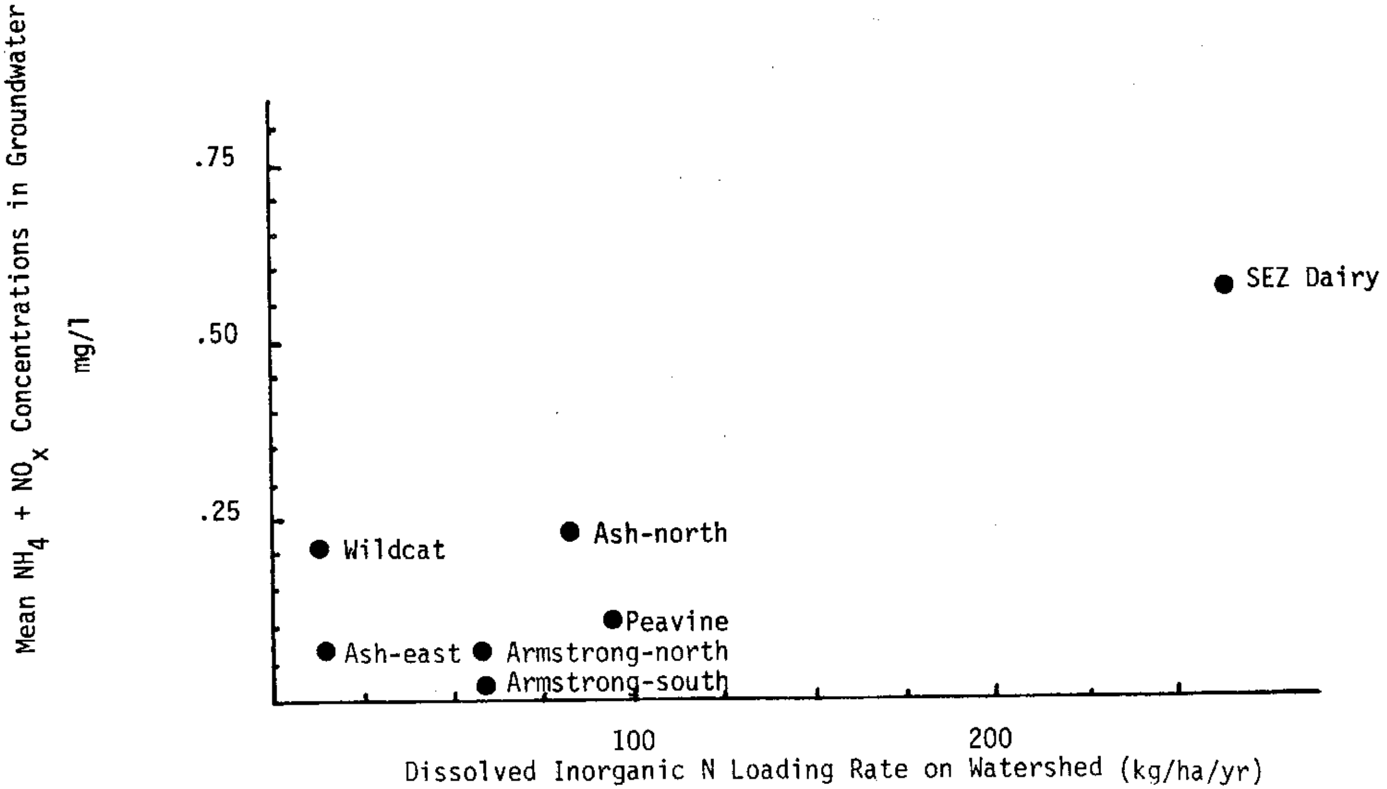


Figure V-60. Mean shallow groundwater concentrations of dissolved inorganic N verses annual surface loading rates.

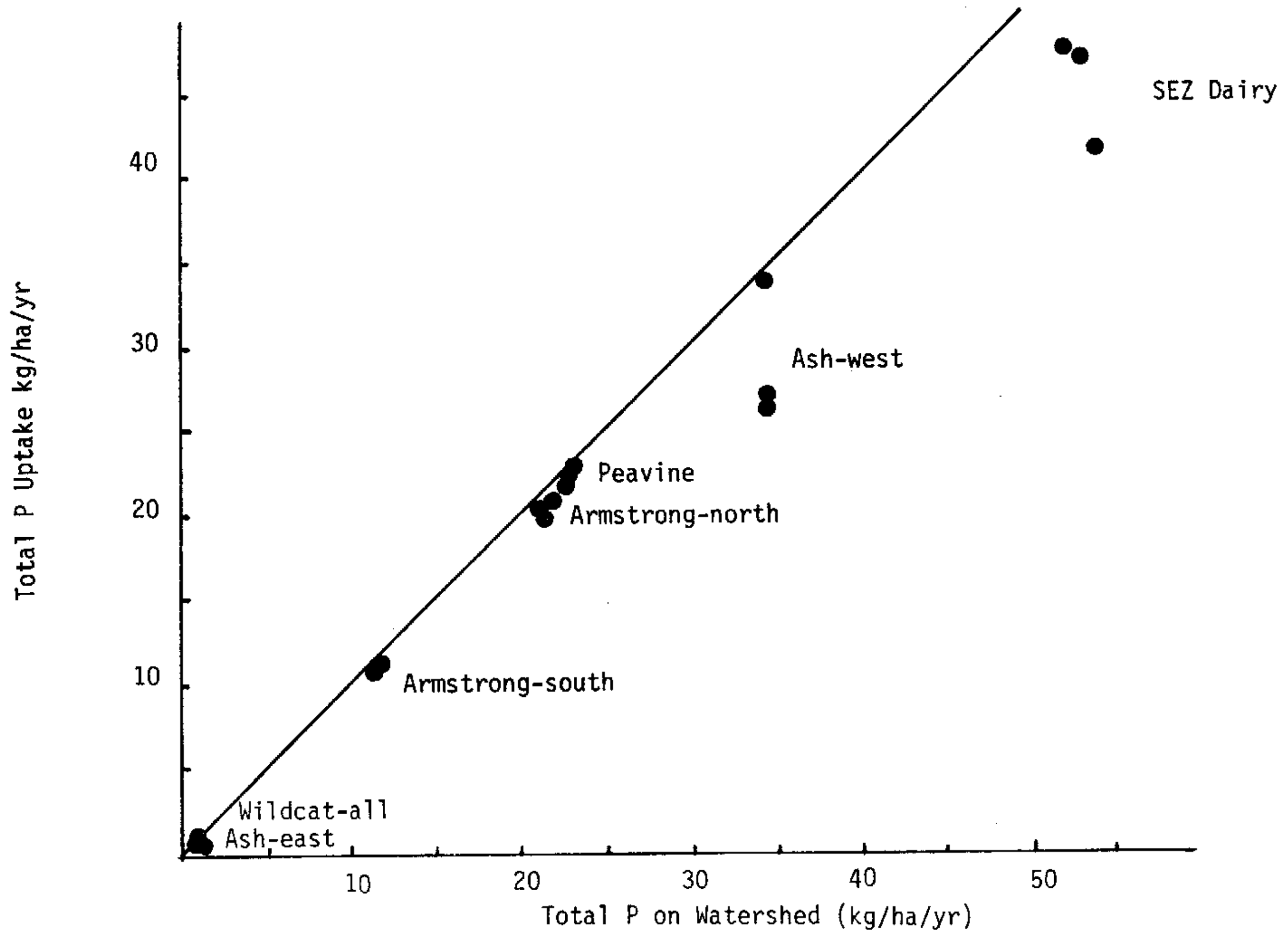
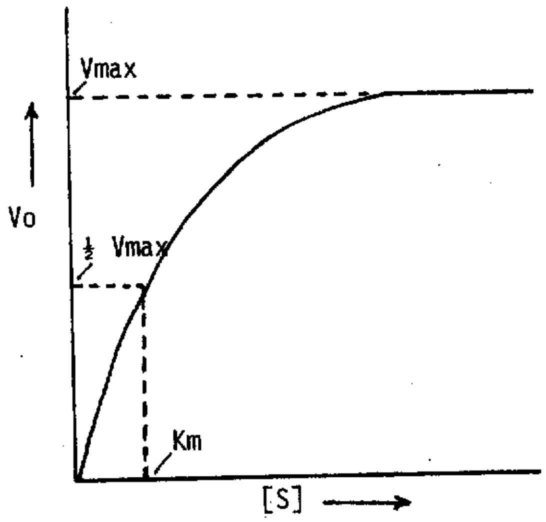


Figure V-61. Total P uptake verses loading on Upland Demonstration Project watersheds.



$$Vo = \frac{Vmax\ [S]}{[S] + Km}$$

Where: Vo = nutrient uptake on watershed
Vmax = maximum nutrient uptake rate on watershed
[S] = nutrient loading rate on watershed
Km = loading rate where uptake rate is ½ Vmax

Figure V-62. Michaelis-Menten Curve and Equation.

one of the criteria that would have to be met either through using compatible practices, limiting the magnitude of incompatible practices, or application of best management practices that would effectively mitigate the impact of incompatible practices.

The response of these watersheds to temporal and magnitude variations in nutrient loading rates is vividly demonstrated by observing changes in monthly flow-weighted concentrations of total N and total P in the discharge monitored from the two watersheds at Ash Slough. The data record there can be conveniently divided into three distinct periods during the study. The first, October 1979 through September 1980, was a period when measurable runoff occurred often enough to provide some continuity of monthly record. The second period, October 1980 through August 1981, was a period when little or no measurable runoff from either watershed occurred and there was, therefore, no export of nutrients. The third and final period began in September 1981 and continued through till the end of the study in September 1982. The last period resembles the first in that discharge from the watershed occurred at frequent enough intervals to allow an almost continuous monthly evaluation of exports.

Flow-weighted total N concentrations in the runoff (Figure V-63) tended to behave somewhat erratic during the first and third periods when measurable runoff occurred, but two distinct characteristics were evident. The first was that on the fertilized west watershed beginning in March-April of each year, there was a distinct rise in flow-weighted concentrations in the runoff. These concentrations peaked at between 3.5 to 4.0 ppm in April-May and then declined to pre-March levels though this decline was much more rapid during the third period than in the first.

The second major characteristic was that except for the period from October 1979 through February 1980 the baseline (or minimum) flow-weighted total N concentrations were consistently in the range of 1.3 to 1.7 ppm for both the fertilized and unfertilized watersheds. If timing and quantity of N loading through fertilizer application is a factor, it seems to manifest itself only during the March through May period when runoff occurs during those months. It is entirely possible that this phenomenon is a response to natural seasonal occurrences such as the onset of significant soil saturation and measurable runoff following a period of antecedent dryness such as were the conditions that preceded both the 1980 and 1982 peaks.

Like Total N, there appeared to be a background total P concentration of about 0.3 ppm in runoff from both the fertilized and unfertilized watersheds, although concentrations in runoff from the unfertilized east watershed tended to remain at or slightly above this level (Figure V-64). Monthly flow-weighted total P concentrations appeared to be very significantly impacted by the periodicity of fertilizer application. Concentrations in runoff from the fertilized western watershed were significantly higher during the first months of rain following the dates of fertilizer application. These concentrations gradually decreased throughout the remainder of the year until they approached the same background concentration noted coming from the unfertilized east watershed.

The landowner indicated that his regular practice was to apply fertilizers in the late part of the year immediately following the cessation of the wet season. This was usually in the month of November. Peak flow-weighted P concentrations occurred in the early spring. It would seem that a portion of the applied P remains on the watershed in unused form until it is dissolved by rainfall and transported away by runoff. Johnston et. al. (1965) found by measuring tile drain effluent from fertilized fields of row crops in California that N losses could amount to as much as 70 percent of that applied and P losses could approach 17 percent. The soils were such that they did tend to fix P. Reddy et. al. (1978) noted that soils have a finite capacity for fixing soluble P, and once active sites are saturated the P concentrations in the soil solution will increase. They noted P movement in soils given various levels of application of beef, poultry, and swine wastes.

Soils typical of the Ash Slough site apparently have poor P fixing capabilities. Thus it is not surprising, given the annual applied loads to the land surface, that dissolved P unassimilated by the surface vegetation would move with the shallow sub-surface lateral flow and surface runoff through the drainage ditches from the site. The P export from SEZ Dairy was consistent with the similar soil types and magnitude of P loading that exceeded that at the Ash Slough site.

In conclusion, intensity of land use (total nutrient load on the watershed per unit time) does impact quality of runoff to receiving waters. While total loading rates do impact the N and P concentrations and export loads in runoff from the watersheds, these study sites assimilated and/or converted nutrients in such a manner that they were less sensitive to the N than they were to P loads. Both N and P are taken up by these watersheds, but the particular inability of the soils to fix and retain P is the probable cause for the enhanced sensitivity.

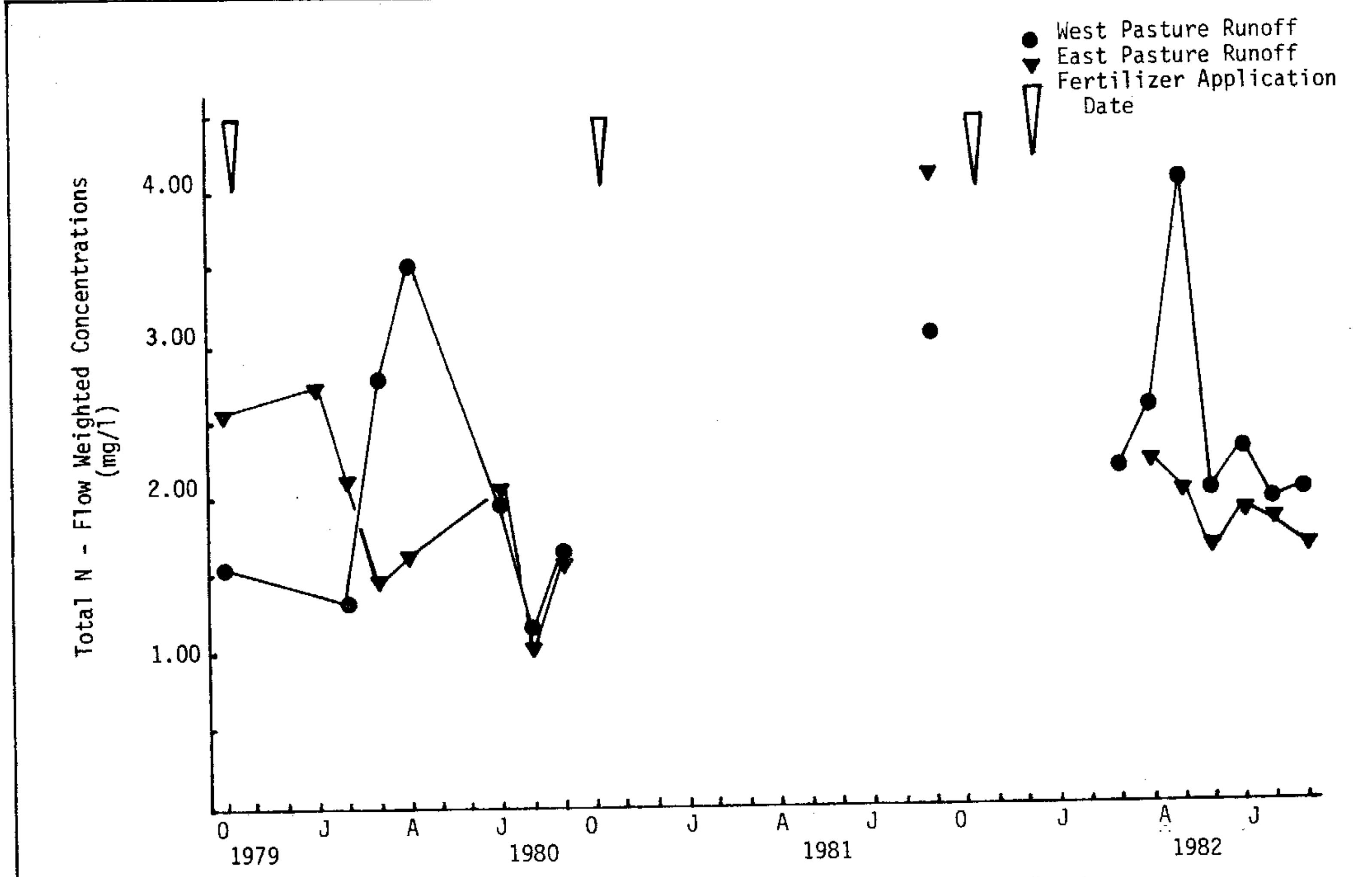


Figure V-63. Monthly flow weighted total N concentrations in runoff from Ash Slough pastures.

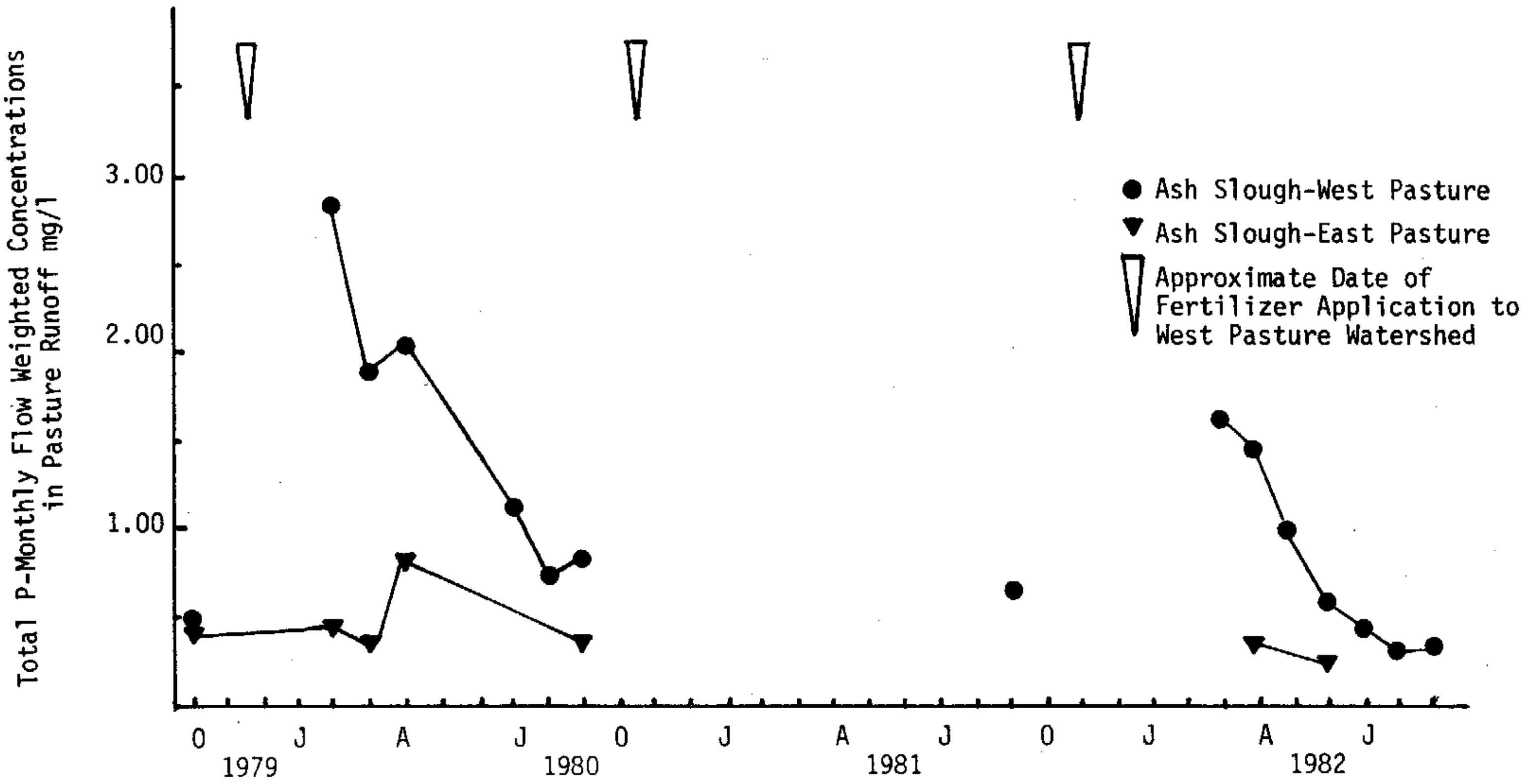


Figure V-64. Monthly flow weighted total P concentrations in runoff from Ash Slough pasture watersheds

SECTION VI
UTILIZATION OF WETLANDS AS DETENTION/ RETENTION FOR ENHANCEMENT OF QUALITY OF NONPOINT SOURCE AGRICULTURAL RUNOFF

INTRODUCTION

Wetlands have the reputation of serving as natural water filters and polishing systems capable of absorbing and/or assimilating large quantities of materials that are considered detrimental to the quality of surface waters (Marshal et al, 1972; Horwitz, 1978). Studies on utilizing wetlands for advanced treatment of municipal wastewaters (particularly nutrient removal) such as those conducted by Boyt, et al (1977), Zoltek (1979), Mudrock and Capobionco (1979), and Kadlac and Hammer (1980) have shown that some wetlands do have at least some absorption or assimilative capacity for nutrients (nitrogen and phosphorus).

Utilization of wetlands as detention/retention (D/R) systems to enhance quality of surface runoff from agricultural lands has been proposed as a best management practice (BMP) to be used as part of any alternative aimed at ensuring the quality of water in the Kissimmee River basin is maintained at desirable levels.

A major focus of effort of the Upland Demonstration Project was to evaluate the effectiveness of wetlands as such D/R facilities. Specific objectives were as follows:

1. First, to compare and contrast two different types of wetlands in the Kissimmee basin. One type is characterized by intermittent accumulation of water in natural low areas. Such wetlands are common throughout the area. Improved pastures and natural range frequently contain such areas which are characterized by standing crops of typical wetland vegetation such as pickeral weed (Pontederia spp.), maidencane (Panicum hemitomon), smartweed (Polygonum punctatum) and St. John's wort (Hypericum spp.).

The alternative type of wetland evaluated was characterized as a recreated, flow-through marsh. An area that had once been part of the backwater flood plain of the pre-channelized Kissimmee River was chosen for this facet of the project. Subsequent to channelization, the area had been ditched and drained and was more typical of improved upland pasture with some low areas subject to frequent inundation from perched rainwater and/or flow to the main channel from the southern tributary. The restoration of this area to a flow-through wetland was a major objective of the project. The methods and manner in which this wetland was restored are described in prior project progress reports (Goldstein et al, 1980; Goldstein, 1980).

2. The second objective was to quantify the nutrient removal capacity of each system.

3. The last major objective was to evaluate the efficiency in which these systems function to remove nutrients as compared to other wetland systems and other types of land uses.

The two wetlands utilized in this study were situated at two of the previously described Upland Demonstration Project study sites, Ash and Armstrong Sloughs. The impacts of land use practices on the contributing watersheds are described in Chapter V of this report.

This section will describe the wetland detention/retention studies in detail, and hopefully provide answers to the questions the study set out to address. The first two sub-sections will discuss results of studies at Ash and Armstrong Sloughs, respectively. The final sub-section will specifically address objective number 3 - that is, to determine the relationship of nutrient processes in these wetlands to those that occur with other types of land use practices.

ASH SLOUGH

The Ash Slough marsh covers approximately 8.1 ha of surface area. It is characterized by intermittent inflow and discharge. When water tables dropped significantly following long antecedent periods without rainfall, the wetland would become dry.

Soil types predominant in the central, and most frequently and longest inundated portions of the marsh are identified by McCollum and Pendleton (1971) and Krottje, et al (1981) as predominantly Felda ponded. This is completely surrounded by an area of predominantly Pompano fine sand, characteristic of the portions of the marsh more commonly subjected to less frequent and shorter periods of inundation. The soils on the periphery of the marsh are predominantly Myakka fine sand as is characteristic of the two contributing watersheds. These are all acid soils with relatively low organic content (6.3 - 12.6 percent) (Krottje, 1981). Climatic conditions during the study have been previously described in Section IV. The marsh was intermittently inundated and dry throughout the three year subject study period. During part of this time the study area was subjected to a severe drought. The Ash Slough marsh experienced a prolonged period (April - August 1981) during which it remained continuously dry. When enough rainfall did eventually occur to flood the marsh in late summer, 1981, it was not of a sufficient amount to result in surface discharge from the system. During the dry period, there was no surface water discharge or nutrient export from the marsh.

For the period of record, October 1, 1979, through September 30, 1982, five distinct inflow/outflow events were observed and monitored at the Ash Slough marsh site. An event was defined as that period from the beginning of measurable inflow into the marsh until the cessation of measurable discharge from the marsh. In reality, a single inflow/discharge event rarely, if ever, occurred triggered by a sole rainfall event. Events were most typically characterized by either a few large, or a series of many small, antcedent rainfall events that saturated the soils in the contributing watersheds. Once the soils were sufficiently wet, subsequent rainfall produced runoff and inflow into the marsh. A similar combination of events would also result in simultaneously inundating part of the marsh. Once the marsh was sufficiently inundated, large rainfall events or multiple small events in series would trigger discharge. Given the nature of the system, a single inflow/discharge event was actually a manifestation of several antecedent and concurrent rainfall events.

The five events (Table VI-1) ranged in duration from as short as 15 days to one of over four months which spanned the entire 1982 wet season.

METHODS

Gaged inflow as well as N and P loads into the marsh from the contributing watersheds were measured at Stations 2 and 4 (Figure II-3). Flow and loadings from rainfall runoff in the ungaged area around the marsh and the marsh itself were estimated using daily rainfall measurements collected at a USGS recording rainfall gauge adjacent to the site. Daily measured rainfall was considered to have fallen on the marsh surface and as such was added to the total water budget on the site. Average concentrations of N and P in rainfall calculated by the method described in Section IV were used in computing estimated nutrient loads from this source. Since measured runoff volume was roughly fifteen percent of total estimated rainfall on the Ash Slough watersheds, this figure was chosen to estimate the surface runoff from total rainfall on the ungaged portion of the watersheds at the periphery of the marsh. Nutrient concentrations for rainfall were used to estimate N and P loads contributed by this source. Estimated loads and water volume from rainfall on the ungaged watershed are listed in Table VI-2. These water and nutrient budgets were calculated in the following manner:

Inflow Sta. 2 + Inflow Sta. 4 + rainfall + ungaged runoff - outflow Sta. 1 = uptake/export

No provisions were made for estimating water loss through either seepage or evapotranspiration. Obviously the component of the water budget that was calculated as "uptake or storage" in the marsh was eventual loss via either or both of these routes.

TABLE VI-1. DATES AND DURATION OF FIVE MONITORED INFLOW/DISCHARGE EVENTS AT THE ASH SLOUGH MARSH

Event No.	Dates	Duration (Days)
1	January 22 - April 22, 1980	85
2	July 15 - August 1, 1980	15
3	August 23 - September 21, 1980	29
4	March 29 - May 12, 1982	45
5	May 27 - September 30, 1982	127

TABLE VI-2. ESTIMATED NUTRIENT LOADS AND WATER VOLUMES CONTRIBUTED TO THE ASH SLOUGH MARSH FROM RAINFALL AND UNGAGED RUNOFF

	Events				
	1	2	3	4	5
Export Total Rainfall in Watershed (m)	.256	.195	.351	20.01	.741
30 Day Antecedent Rainfall on Watershed (m)	.009	.076	.064	16.05	.030
Event Total Rainfall on Marsh Surface (m^3)	14,592	11,115	20,007	11,406	42,237
Event Total Rainfall on Remainder of Ungaged Watershed (m^3)	33,024	25,155	45,279	25,812	95,589
Estimated Runoff from Ungaged Watershed to Marsh (m^3)	4,954	3,773	6,792	3,872	14,338
Load in Rainfall in Marsh (kilograms)					
Inorganic N	10.07	7.67	13.80	7.87	29.14
Total N	22.47	17.12	30.81	17.57	65.04
Ortho P	0.88	0.67	1.20	0.68	2.53
Total P	1.40	1.07	1.92	1.95	4.05
Load to Marsh in Runoff From Ungaged Watershed (kilograms)					
Inorganic N	3.42	2.60	4.69	2.67	9.89
Total N	7.63	5.81	10.46	5.96	22.08
Ortho P	0.30	0.23	0.41	0.232	0.86
Total P	0.48	0.36	0.65	0.372	1.38

Total Ungaged Watershed	186,000 m^2
Marsh Surface	57,000 m^2
Remainder of Ungaged Watershed	129,000 m^2

Rainfall Concentrations

Inorganic N	0.69 mg/L
Total N	1.54 mg/L
Ortho P	0.60 mg/L
Total P	.096 mg/L

Uptake mechanisms for N and P are either vegetative uptake, mineralization and subsequent loss to the atmosphere (for N), storage in sediment, and/or loss from the system through seepage out to deeper groundwater or through shallow lateral subsurface flow. Given the porous and permeable nature of the soils the loss to groundwater is a distinct possibility, but since this study was focused on impacts on surface waters the magnitude of the groundwater loss was not addressed and as such remains unknown.

EVENT 1

The first event occurred in January through April, 1980. Measurable inflow to the marsh began on January 28, and outflow ceased on April 22. Rainfall on the watershed measured at the site during the period was 25.6 cm. Rainfall during the 30 day period antecedent to the beginning of the inflow was 0.9 cm. The water and nutrient budget for the first event at the Ash Slough marsh are presented in Table VI-3. It is assumed that where the percentage of nutrient uptake exceeds the percentage of water loss that uptake mechanisms are active in the marsh. In those cases when percentage of nutrient uptake is less than the percentage of water loss, it might be assumed that active uptake mechanisms are inefficient or that the marsh substrate is actively undergoing some loss of nutrients through internal cycling. Where nutrient uptake is equivalent to water loss measured in the system, the uptake mechanism in the marsh is assumed to be passive, that is storage or loss is due solely to the storage or loss of the equivalent percentage of the water budget.

During the first event, there was a storage/uptake of water in the marsh of 46,216 m^3 or 30 percent of the inflow. During the same period, 15.6 kg of inorganic N, 124 kg of total N (108 kg in particulate form), 92 kg of ortho P, and 116 kg of total P (24 kg in the particulate form) were taken up. These amounted to 78.4, 29.0, 39.3, and 41.0 percent respectively of the influx of each species. Since the percentage of total N uptake was equivalent to the water storage, it is assumed that net uptake by the marsh was not occurring. The dissolved inorganic N component, however, did exhibit a substantial loss indicating that these species were actively taken up by vegetation or else lost through nitrification/denitrification processes. Though there was substantial reduction in the amount of dissolved inorganic N, the relatively small amount of these species in the total N inflow (8.6 percent) was not sufficient to result in a marked reduction in the total N as particulate organic forms (presumably from senesced and decomposed vegetation) passing from the marsh seemed to completely compensate for the loss of inorganic species. In fact particulate N reduction was only 26.6 percent which was less than that expected from water loss/storage in the system.

Total P reduction was about 10 percent greater than water loss/storage indicating that some uptake or loss to sediment was occurring. This occurred for both dissolved and particulate forms. Almost 83 percent of the P load in the inflow to the marsh occurred in the dissolved ortho form. Over 79 percent of the outflow P was in the ortho form.

Time series data of daily inflow/discharge, total N, and total P concentrations are depicted in Figures VI-1 through VI-3. The discharge hydrograph at Station 1 closely resembles the inflow hydrograph at Station 2, which receives runoff from the larger, ditched watershed. Concentrations of total P at the outfall of the marsh closely resemble those measured at Station 2 both in trends and magnitude. This is not surprising since the west watershed contributes over 81 percent to the total marsh inflow whereas the smaller, eastern watershed contributes roughly 6.5 percent of the total inflow. Trends in concentration changes (peaks and valleys) at the Station 1 outflow seem to lag behind those at Station 2 inflow point by 3-12 days for total P. Total N peaks and valleys at the Station 1 outflow appear to be in phase and of almost the same magnitude as concentrations at the Station 2 inflow throughout all but the first 20 days of the event. During that time, concentrations at Station 1 more closely reflect those noted at the Station 4 inflow. Total N concentrations at Stations 2 and 1 appeared to be gradually increasing throughout the duration of the event while concentrations at Station 4 seemed to decline slightly.

In summary, during this first event, the marsh served as a net sink for both N and P though the total N uptake could be accounted for entirely by water storage/loss in the system. The marsh appeared to be actively taking up P, but in amounts only about 10 percent greater than loss through storage.

EVENT 2

The second event monitored at the Ash Slough marsh occurred over the period July 15 through August 1, 1980. Rainfall on the watershed during the period was 19.5 cm. The event was preceded by a 30-day antecedent period in which 7.6 cm of rainfall occurred.

The water and nutrient budgets for this event are presented in Table VI- 4. During this event, there was storage/uptake of water in the marsh of 75,323 m^3 or almost 83 percent of the total inflow. At the same

TABLE VI-3. WATER AND NUTRIENT BUDGET FOR THE ASH SLOUGH MARSH EVENT #1
January 22, 1980 - April 22, 1980

Input Stations = Total Input + Rainfall = Total In - Total Out = Uptake/Export

	Input Station 4	Input Station 2	Total Input	Estimated Ungaged Rainfall	Total In	Total Out	Uptake/	Export
Water Budget (m^3)	10,032	124,544	134,576	19,546	154,122	107,906	46,216	(30.0%)
Inorganic N (kg)	.586	23	23.6	13.49	37.09	8	29.09	(78.4%)
Total N (kg)	18.31	380	398	30.10	428	304	124	(29.0%)
Ortho P (kg)	3.058	230	233	1.18	234	142	92	(39.3%)
Total P (kg)	4.319	277	281	1.88	283	167	116	(41.0%)

TABLE VI-4. WATER AND NUTRIENT BUDGET FOR THE ASH SLOUGH MARSH EVENT #2
July 15, 1980 - August 1, 1980

Input Stations = Total Input + Rainfall = Total In - Total Out = Uptake/Export

	Input Station 4	Input Station 2	Total Input	Estimated Ungaged Rainfall	Total In	Total Out	Uptake/	Export
Water Budget (m^3)	978	75,119	76,097	14,888	90,985	15,662	75,323	(82.8%)
Inorganic N (kg)	0.030	3	3	10.27	13.27	1	12.27	(92.5%)
Total N (kg)	1.64	149	152	22.93	175	26	149	(85.1%)
Ortho P (kg)	0.306	74	74	0.90	75	13	62	(82.7%)
Total P (kg)	0.400	86	86	1.43	87	15	72	(82.8%)

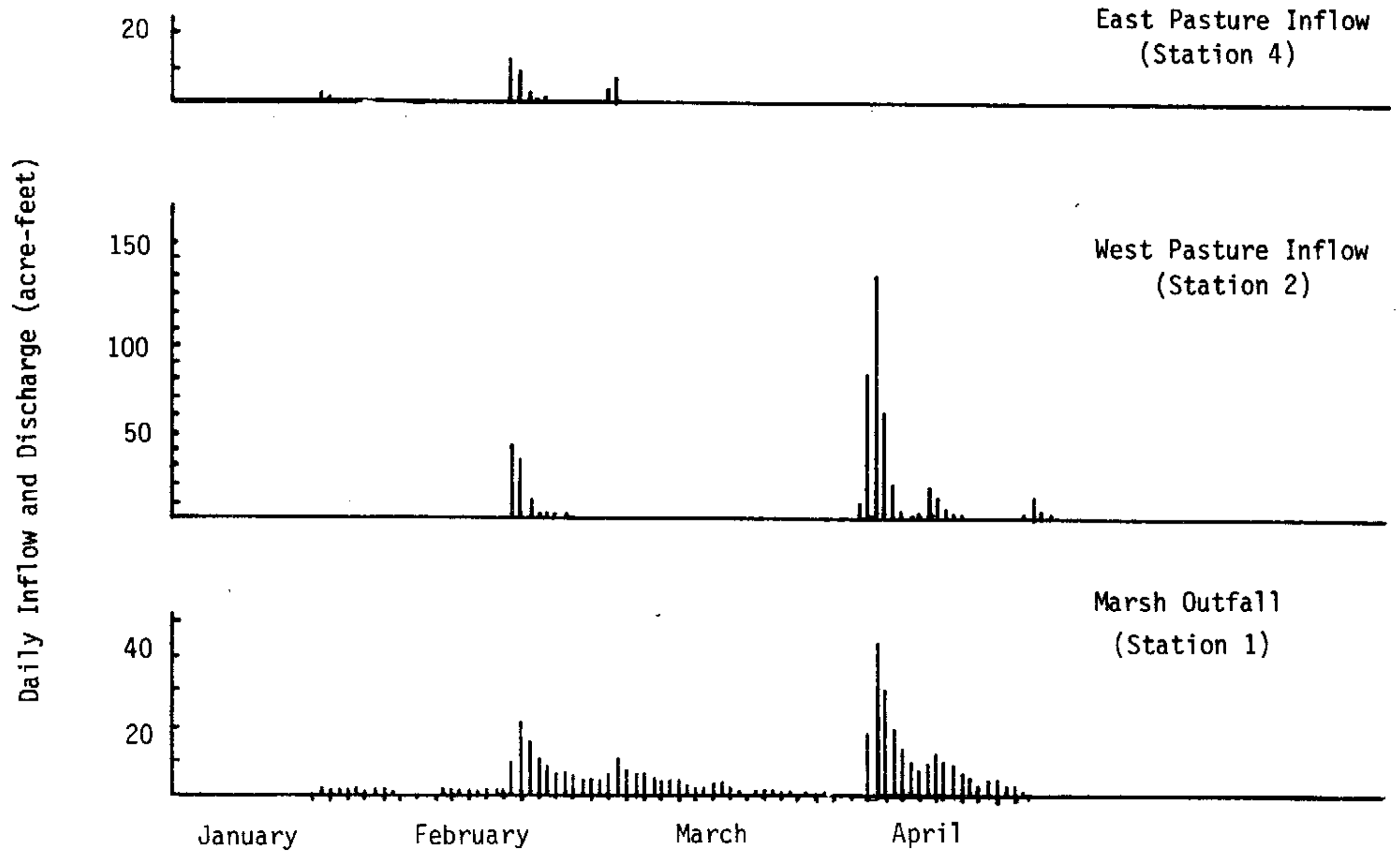


Figure VI-1. Daily inflow and discharge at the Ash Slough wetland during Event #1.

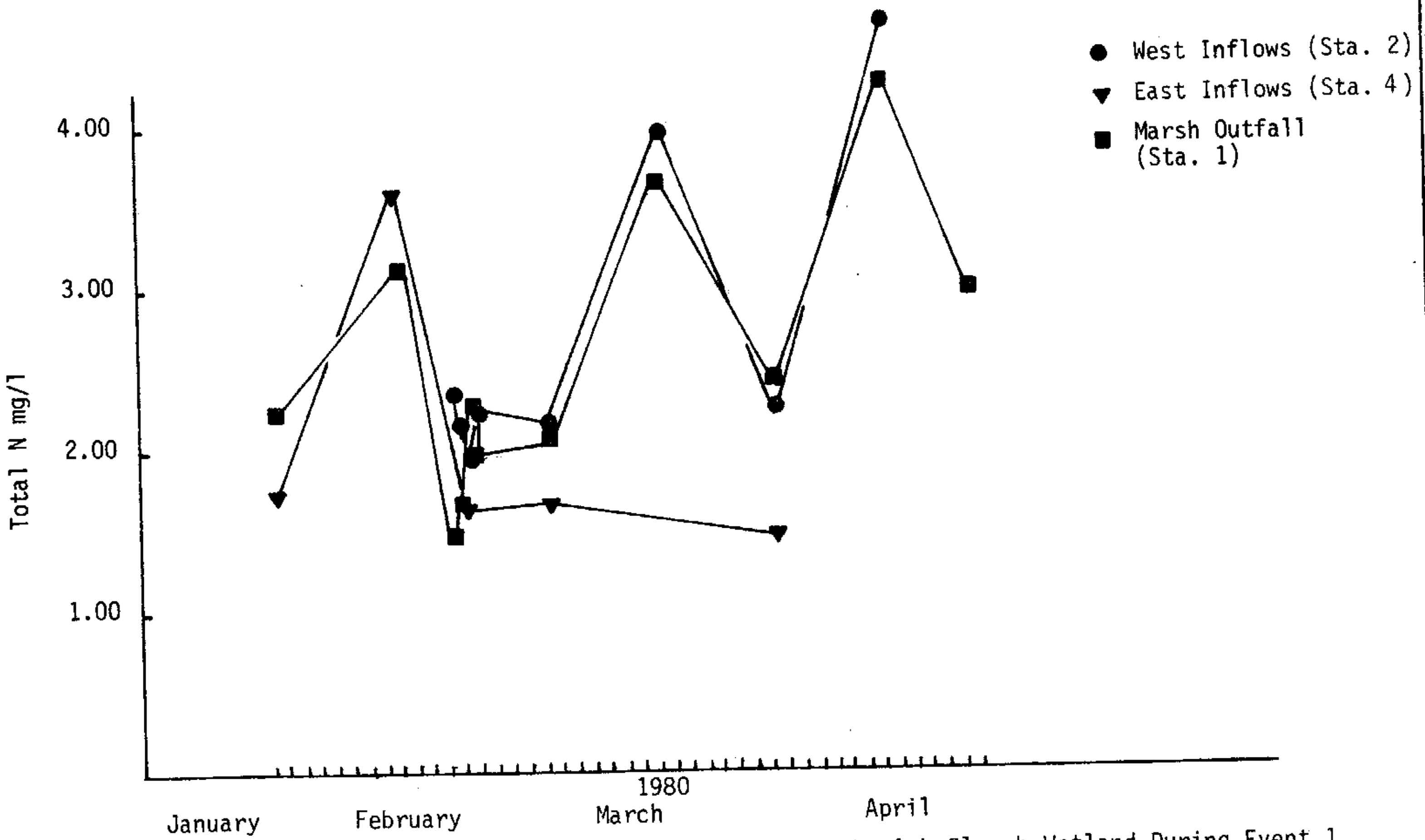


Figure VI-2. Time Series Concentrations of Total Nitrogen at the Ash Slough Wetland During Event 1 (January 27 - April 22, 1980).

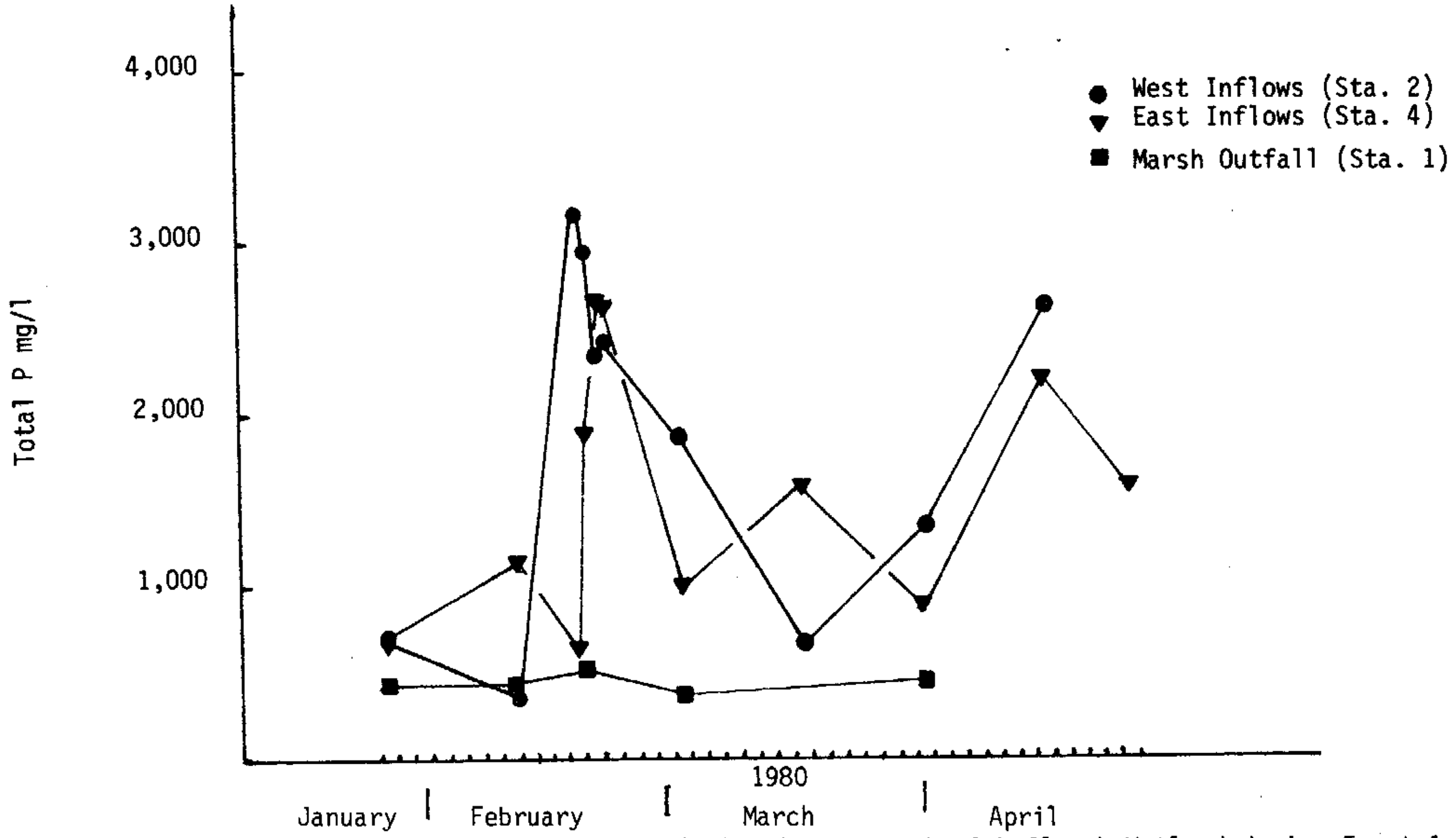


Figure VI-3. Time series concentrations of Total Phosphorus at the Ash Slough Wetland during Event 1 (February 27 - April 22, 1980).

time, 12.27 kg of dissolved inorganic N, 149 kg of total N (about 137 kg in the particulate organic form), 62 kg of ortho P, and 72 kg of total P (10 kg in particulate form) were also removed. These were 92.5, 85.1, 82.7, and 82.8 percent respectively of the total load of these species into the marsh. Uptake of both dissolved and particulate P species can be attributed entirely to passive loss associated with the loss/storage of water in the marsh. Inorganic N species appear to be actively taken up in the marsh since the percentage of uptake exceeds that of water storage/loss by 10 percent. Active uptake above loss to storage of particulate organic N, if any, is slight or insignificant.

Time series data of daily inflow/discharge, total N, and total P concentrations are depicted in Figures VI-4 through VI-6. Runoff contributions from the small eastern watershed were negligible during this event. Increases, peaks, and declines in discharge at the site outfall were in phase with, but of significantly less magnitude than, those same trends at the Station 2 inflow. Total P from the Station 2 inflow increased slightly from initial concentrations before leveling off, whereas concentrations at the Station 4 monitoring site declined before stabilizing. Total P concentrations at the outfall (Station 1) followed the Station 2 trends, but were again of slightly less magnitude until late in the event (day 13) when they exceeded those measured at Station 2.

Total N concentrations at the three stations were most unlike at the beginning of the event. Concentrations at all stations increased gradually throughout the duration of the event, following the same trends, and were virtually identical at all stations on the final day of the event.

In summary, during event number 2, uptake of N and P in the marsh was largely passive (i.e. an artifact of the loss or storage of water in the system). There was some active uptake or mineralization of dissolved inorganic N, but the small quantities present had little overall impact on total N uptake.

EVENT 3

Inflow into the marsh at the commencement of the third event began on August 23, 1980. The event lasted a total of 28 days ending with the cessation of outflow on September 21, 1980. Rainfall on the watershed during the subject period measured 35.1 cm. During the 30-day period antecedent to the event rainfall in the area was 6.4 cm.

During this event, there was a storage/uptake of water in the marsh of 59,834 m^3 or 25.8 percent of the total inflow, (Table VI-5). During the same period 21, 50, 58, and 62 kilograms of dissolved inorganic N, total N, ortho P, and total P respectively were taken up by the marsh. This amounted to 84.0, 13.7, 38.7, and 36.9 percent respectively of the total influx of these nutrients into the marsh over this period. The percentage of uptake suggests that the marsh was actively removing dissolved inorganic N and ortho P. The percentage of particulate P removed (22.2 percent) was less than that expected by passive uptake storage which suggests that while there is some uptake of dissolved forms, some concurrent flushing of P from the marsh may occur as particulate organic material (i.e. detritus). By the same token, particulate N removal was much less efficient then that expected by mere storage (only 8.5 percent). This, coupled with the fairly efficient uptake of dissolved inorganic N, suggests that there may be some loss of N via particulate organic material.

Time series discharge and N and P concentration data are depicted in Figures VI-7 through VI-9. The most striking trend is the apparent inverse relationship between inflow peaks and total N concentrations at both the inflow and outflow stations. This suggests that a dilution phenomenon for this species occurs in both the contributing watersheds and the marsh. Nitrogen concentrations in outflow from the marsh reflected both the trends and magnitude of concentrations noted with the inflow from the two contributing watersheds. In general, concentrations at Station 1 were slightly less than those at Station 2, while at the same time they remained slightly higher than those in the inflow from the eastern watershed (Station 4).

Phosphorus concentrations at both the inflow stations and the outfall station increased at the beginning of the event. After the initial rise they leveled off and then began a gradual decline throughout the duration of the event. As in the other events discussed, concentrations at the outfall station reflected trends and magnitude at the Station 2 inflow. Concentrations at the Station 4 inflow were usually less than half the magnitude of those measured at Station 2.

In summary, the marsh acted as a net sink for N and P during the third event. There was evidence to suggest that the major mechanism of nutrient reduction is uptake or loss of the dissolved species of N and P, whereas the marsh may in fact be in a near equilibrium state with regard to organically bound N and P as the efficiency of particulate nutrient reduction was less than that which could be attributed to passive storage in the system due to water loss alone.

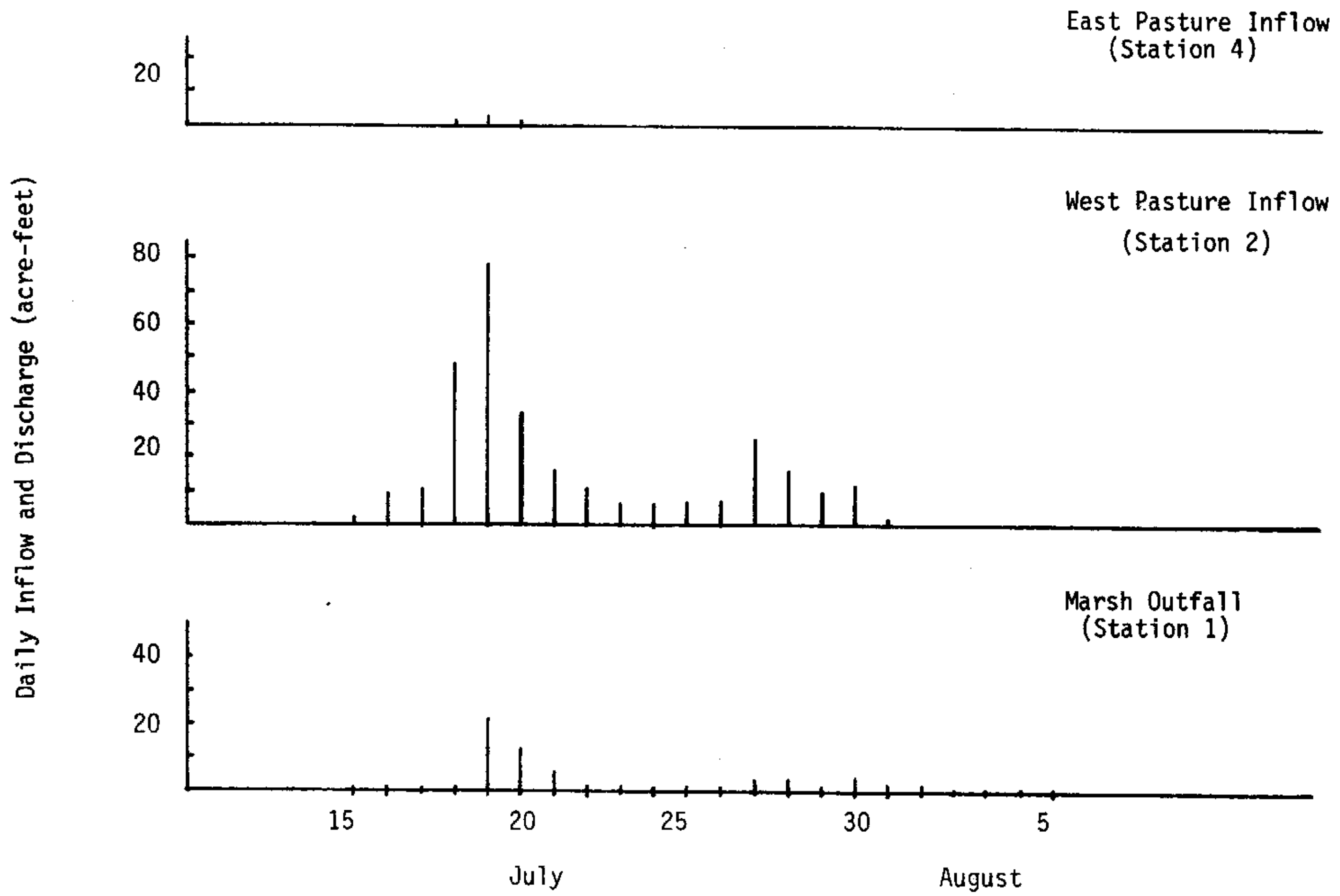


Figure VI-4. Daily inflow and discharge at Ash Slough wetland during Event #2.

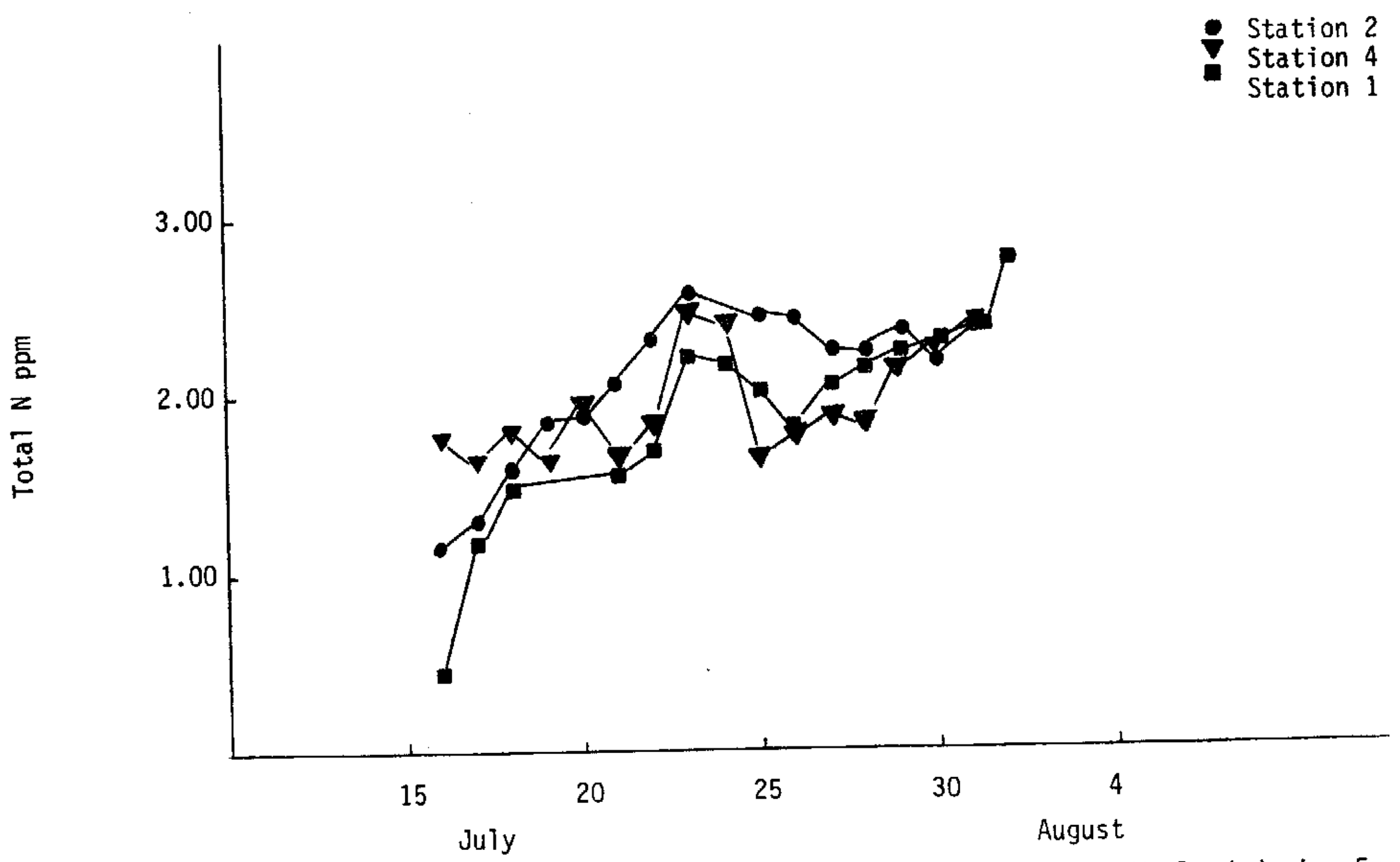


Figure VI-5. Time series concentrations of Total Nitrogen at the Ash Slough Wetland during Event #2. (July 15 - August 1, 1980).

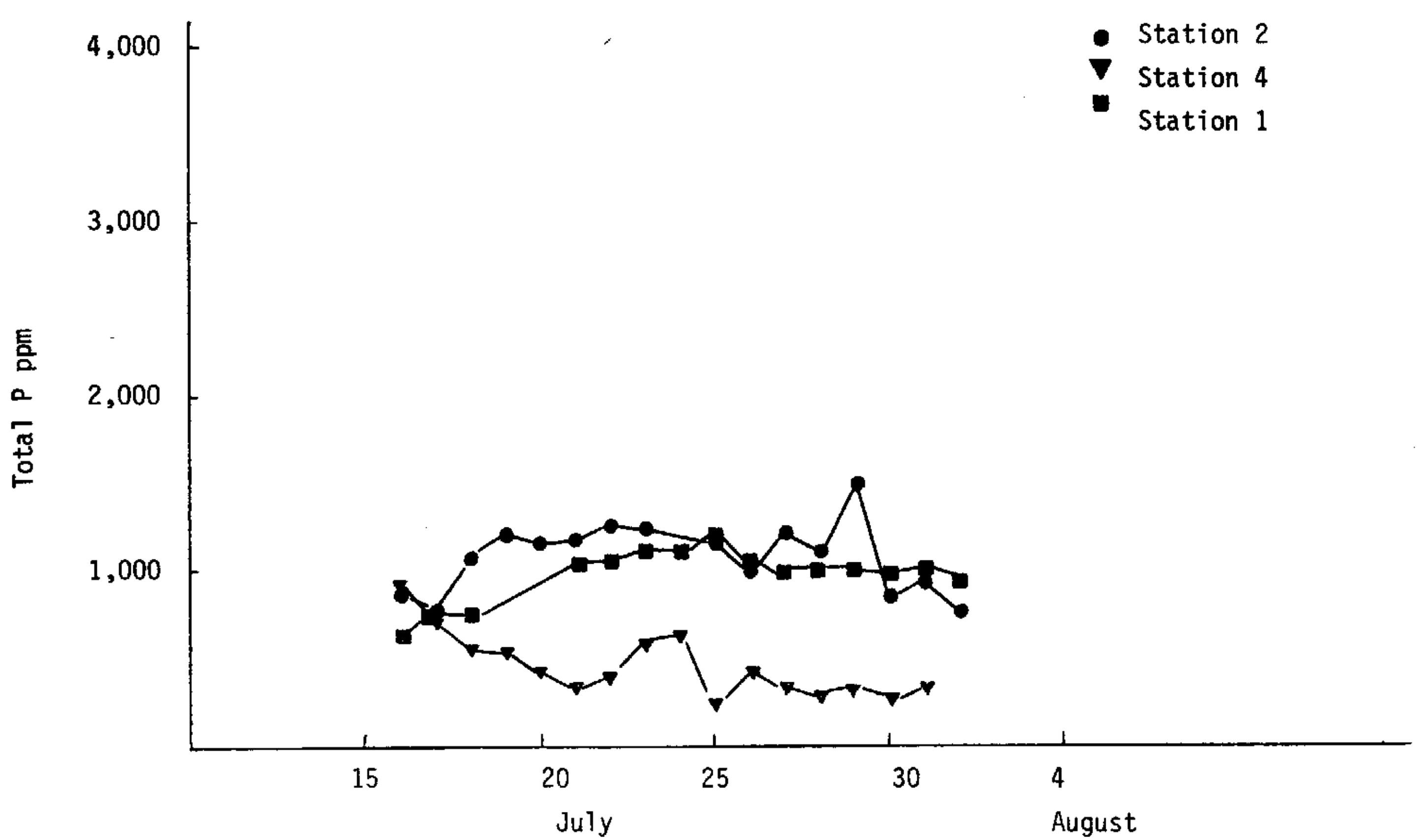


Figure VI-6. Time series concentrations of Total Phosphorus at the Ash Slough Wetland during Event #2 (July 15 - August 1, 1980).

TABLE VI-5. WATER AND NUTRIENT BUDGET FOR THE ASH SLOUGH MARSH EVENT #3
August 23, 1980 - September 21, 1980

Input Stations = Total Input + Rainfall = Total In - Total Out = Uptake/Export

	Input Station 4	Input Station 2	Total Input	Estimated Ungaged Rainfall	Total In	Total Out	Uptake/	Export
Water Budget (m^3)	12,234	193,056	205,290	26,799	232,089	172,255	59,834	(25.8%)
Inorganic N (kg)	0.32	7	7	18.49	25	4	21	(84%)
Total N (kg)	18.51	306	325	41.27	366	316	50	(13.7%)
Organic Particulate N	18.19	299	318	22.78	341	312	29	(8.5%)
Ortho P (kg)	3.52	144	148	1.61	150	92	58	(38.7%)
Total P (kg)	4.55	160	165	2.57	168	106	62	(36.9%)
Particulate P	1.03	16	17	.96	18	14	4	(22.2)

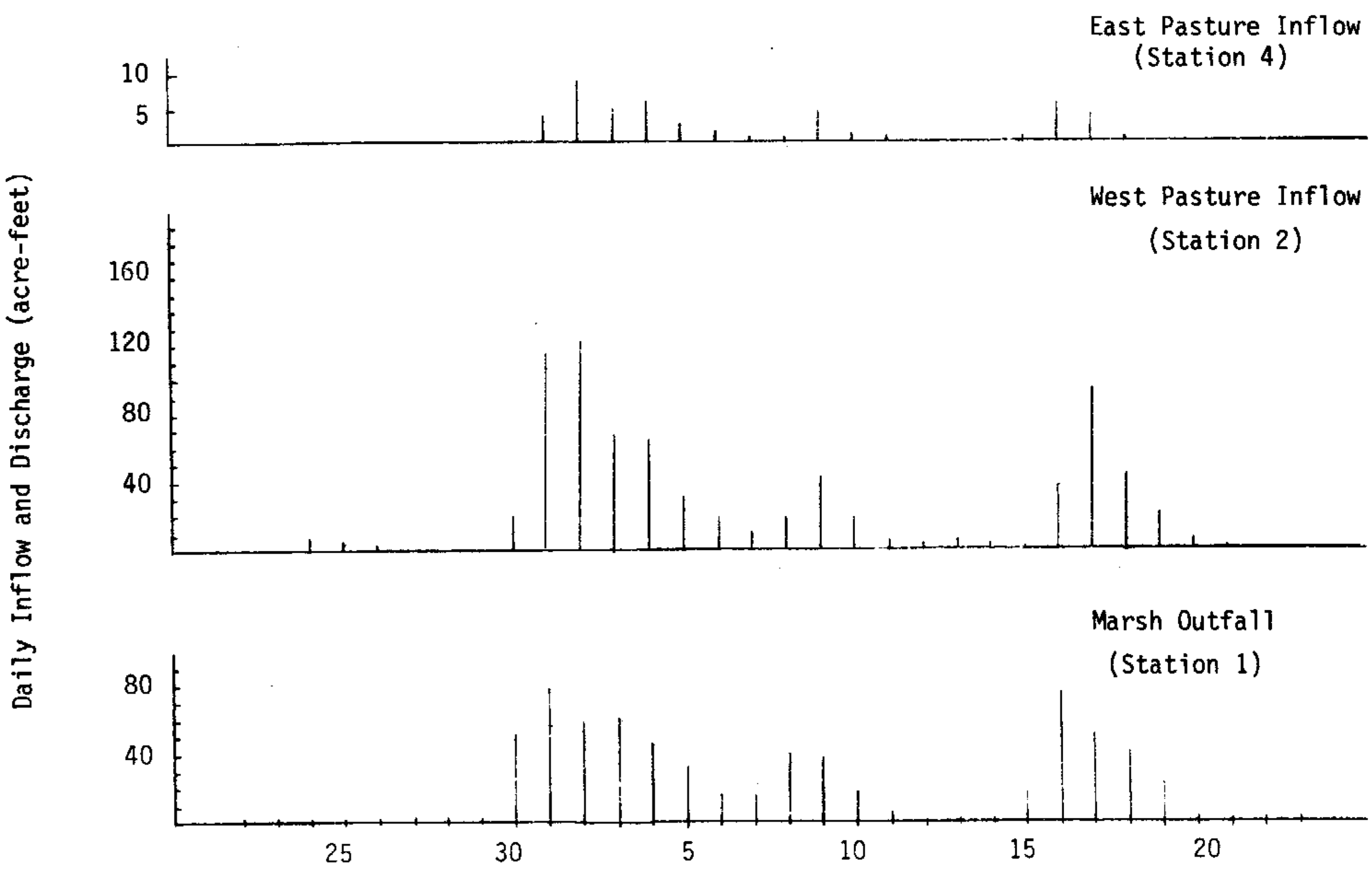


Figure VI-7. Daily inflow and discharge at the Ash Slough wetland during Event #3.

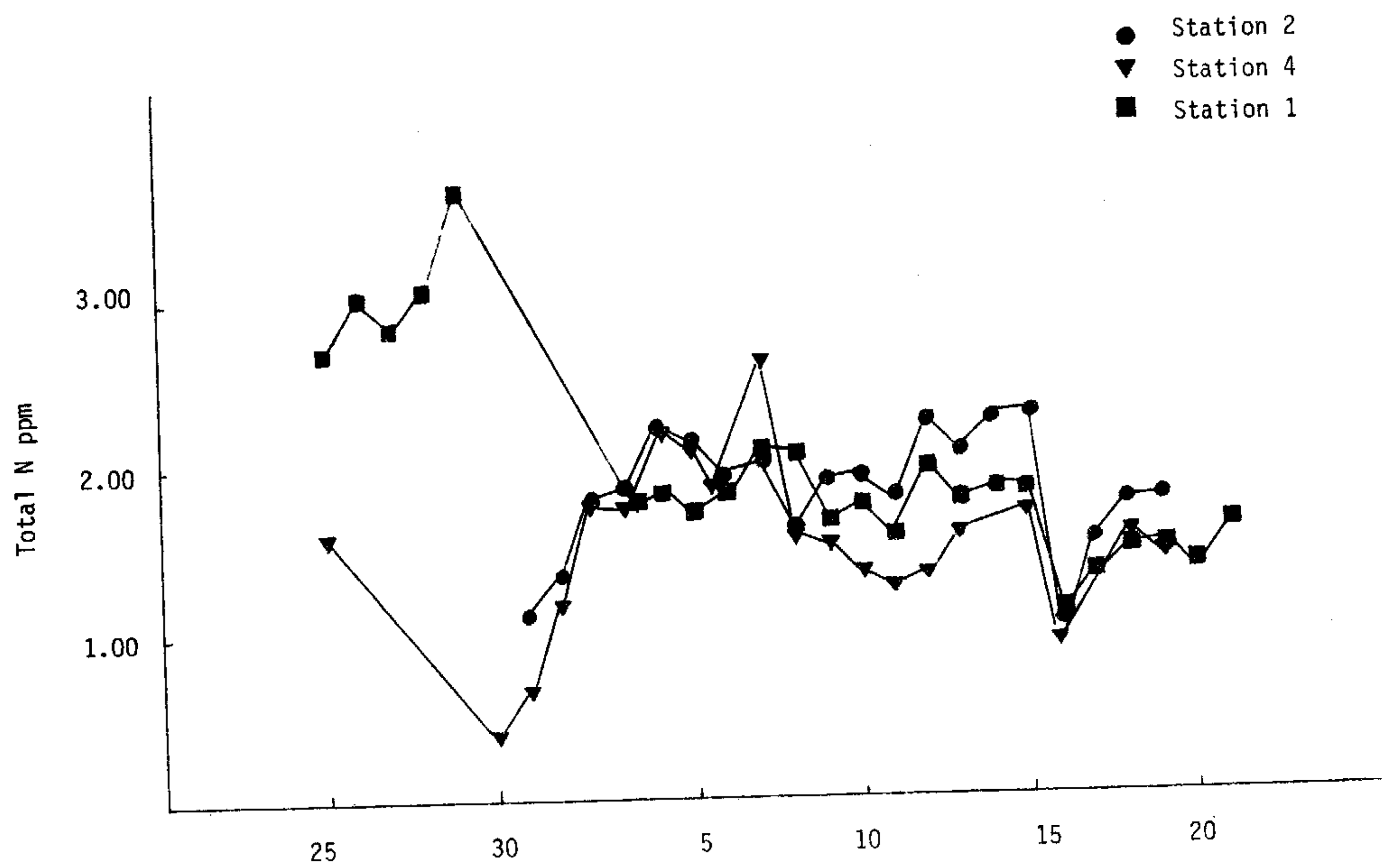


Figure VI-8. Time series concentrations of Total Nitrogen at the Ash Slough Wetland during Event #3 (August 23 - September 21, 1982).

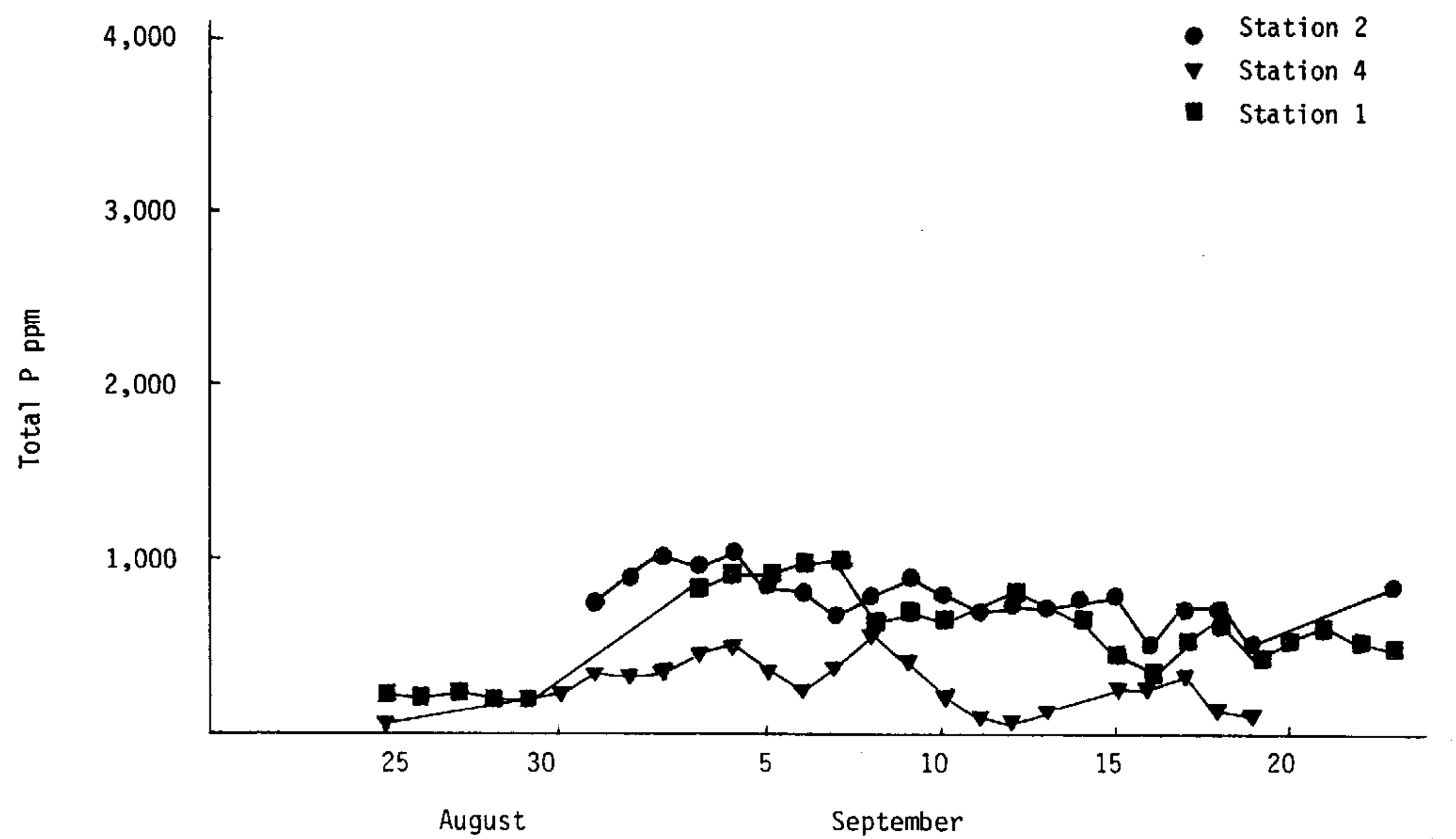


Figure VI-9. Time series concentrations of Total Phosphorus at the Ash Slough Wetland during Event #3. (August 23 - September 21, 1980).

EVENT 4

Of the five monitored events, event 4 was the third shortest in duration (45 days), spanning the period March 29 through May 12, 1982. Rainfall records at the site were incomplete for the subject time period. Of the three surrounding WMD rainfall network gauges only one, Micco Bluff (MRF159), had a complete daily rainfall record for the subject period. The Micco Bluff gauge was roughly 8 miles from the study site. Available records at the other gauges, Maxcy South, (MRF 190) and Basinger, (WM 160), suggest that rainfall at the Micco Bluff gauge was representative of amounts that fell area-wide. During the months of March, April, and May, rainfall totals are more apt to be relatively consistent throughout the area due to the nature of large scale rain generating systems that occur during these months. This would not necessarily be the case later in the summer months as rainfall would be more apt to be of the spotty and locally heavy nature thereby undermining the reliability of the estimate. Given the time of year, nature of the rain generating systems, and the consistency of available data, daily rainfall at the Micco Bluff gauge was judged to be fairly accurate for use to estimate the ungaged water and nutrient contributions to the Ash Slough marsh during this event.

Total rainfall on the marsh and contributing watersheds was estimated to be 20.01 cm during the event. Rainfall on the area during the 30 day period antecedent to the event was estimated to be 16.05 cm. Rainfall on the day immediately preceding the beginning of the event (March 28) was 6.28 cm. The water and nutrient budget for this event is depicted in Table VI-6. There was storage/uptake of water in the marsh of 50,267 m^3 or roughly 24.1 percent of the total inflow. Simultaneously, 15.5 kg dissolved inorganic N, 16 kg of particulate organic N, 82 kg of ortho P, and 2 kg of particulate P was taken up or stored in the marsh resulting in reduction efficiencies of 54.4, 3.3, 30.5, and 8.0 percent respectively. Total N reduction efficiency was 6.3 percent while that for total P was 28.6 percent. Dissolved constituents of N and P loads were taken up in excess of loss that could be attributed to storage or loss of water in the marsh. Uptake of dissolved inorganic N was more efficient, however, than ortho P uptake, which was only slightly greater than that expected by water volume loss. Uptake of particulate N and P was particularly poor indicating that these materials were either flushed through the system or the marsh contributed such materials through detritus export almost as quickly as it was being removed. During this event the marsh functioned particularly poorly in uptake as total N and almost all total P uptake could be attributed to passive storage.

Time series inflow/discharge and N and P concentration data are depicted in Figures VI-10 through VI-12. Almost all of the gauged flow through the marsh during this event was observed to be coming from the larger western watershed (Station 2). Trends in periodicity and peaks in discharge rates at Station 1 resemble the Station 2 hydrograph and differ primarily in magnitude.

Total N concentrations at Stations 2 and 4 appear to rise and fall in inverse relationship to measured discharge. This suggests that dilution is a major factor. Concentrations at Station 1 tend to follow similar trends but they are less variable. Total N concentrations reach their maximum at all three stations near the end of the event.

Total P concentrations in the marsh show three major traits. First, like total N, concentrations tend to decrease during periods of peak flows into or out of the marsh, secondly concentrations at Stations 2 and 1 are essentially the same, while concentrations measured at Station 4 are substantially less. Concentrations at Station 1 continue to be influenced primarily by nutrient levels at the major inflow source. The last noticeable characteristic of P concentrations during this event is the gradual decline of concentrations throughout the duration of the subject period. This is especially noticeable at Station 1 subsequent to the cessation of inflow into the system.

In summary, the marsh continued to act as an N and P sink particularly for dissolved species. Active uptake of particulate components, if any, is offset by export of almost the same quantity from the system. Uptake associated with loss/storage is again the primary mechanism of nutrient reduction.

EVENT 5

Beginning with inflow into the marsh on May 27, a series of rainfall/runoff events occurred in rapid enough succession to result in continuous discharge through the 1982 wet season. Though the discharge event was still in progress, the study was terminated on September 30, 1982 and for the purposes of this report, the event was considered to have ended at that time.

Rainfall during the subject period measured on the site was 74.1 cm. Only 3.0 cm of rainfall was measured on the site during the 30-day antecedent period. The water and nutrient budgets for the event are presented in Table VI-7. During the event, almost

TABLE VI-6. WATER AND NUTRIENT BUDGET FOR THE ASH SLOUGH MARSH EVENT #4
March 29, 1982 - May 12, 1982

Input Stations = Total Input + Rainfall = Total In - Total Out = Uptake/Export

	Input Station 4	Input Station 2	Total Input	Estimated Ungaged Rainfall	Total In	Total Out	Uptake/	Export
Water Budget (m^3)	2,936	190,611	193,547	15,278	208,825	158,558	50,267	(24.1%)
Inorganic N (kg)	.125	18	18	10.54	28.54	13	15.54	(54.4%)
Total N (kg)	6.21	479	485	23.53	509	477	32	(6.3%)
Ortho P (kg)	.65	267	268	.91	269	187	82	(30.5%)
Total P (kg)	1.15	291	292	2.32	294	210	43	(28.6%)

TABLE VI-7. WATER AND NUTRIENT BUDGET FOR THE ASH SLOUGH MARSH EVENT #5
May 27, 1982 - September 30, 1982

Input Stations = Total Input + Rainfall = Total In - Total Out = Uptake/Export

	Input Station 4	Input Station 2	Total Input	Estimated Ungaged Rainfall	Total In	Total Out	Uptake/	Export
Water Budget (m^3)	23,489	371,928	395,417	56,575	451,992	341,087	110,905	(24.5%)
Inorganic N (kg)	0.63	28	29	39.03	68	47	21	(30.9%)
Total N (kg)	40.96	783	824	87.12	911	897	14	(1.5%)
Ortho P (kg)	2.51	134	136.51	3.39	139.9	60	79.9	(57.1%)
Total P (kg)	4.43	186	190	5.43	195	112	83	(42.6%)

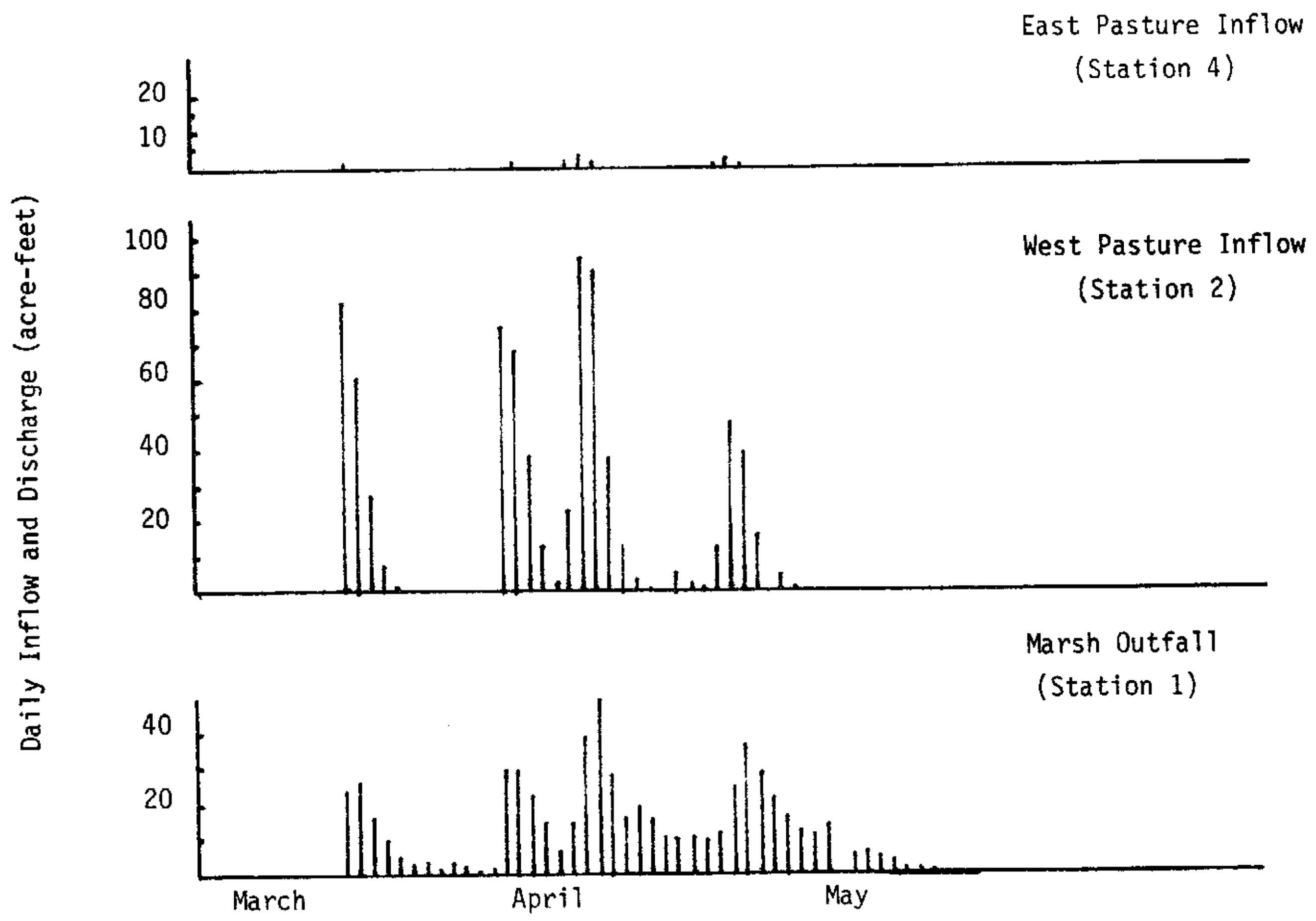


Figure VI-10. Daily Inflow and Discharge at Ash Slough During Event #4.

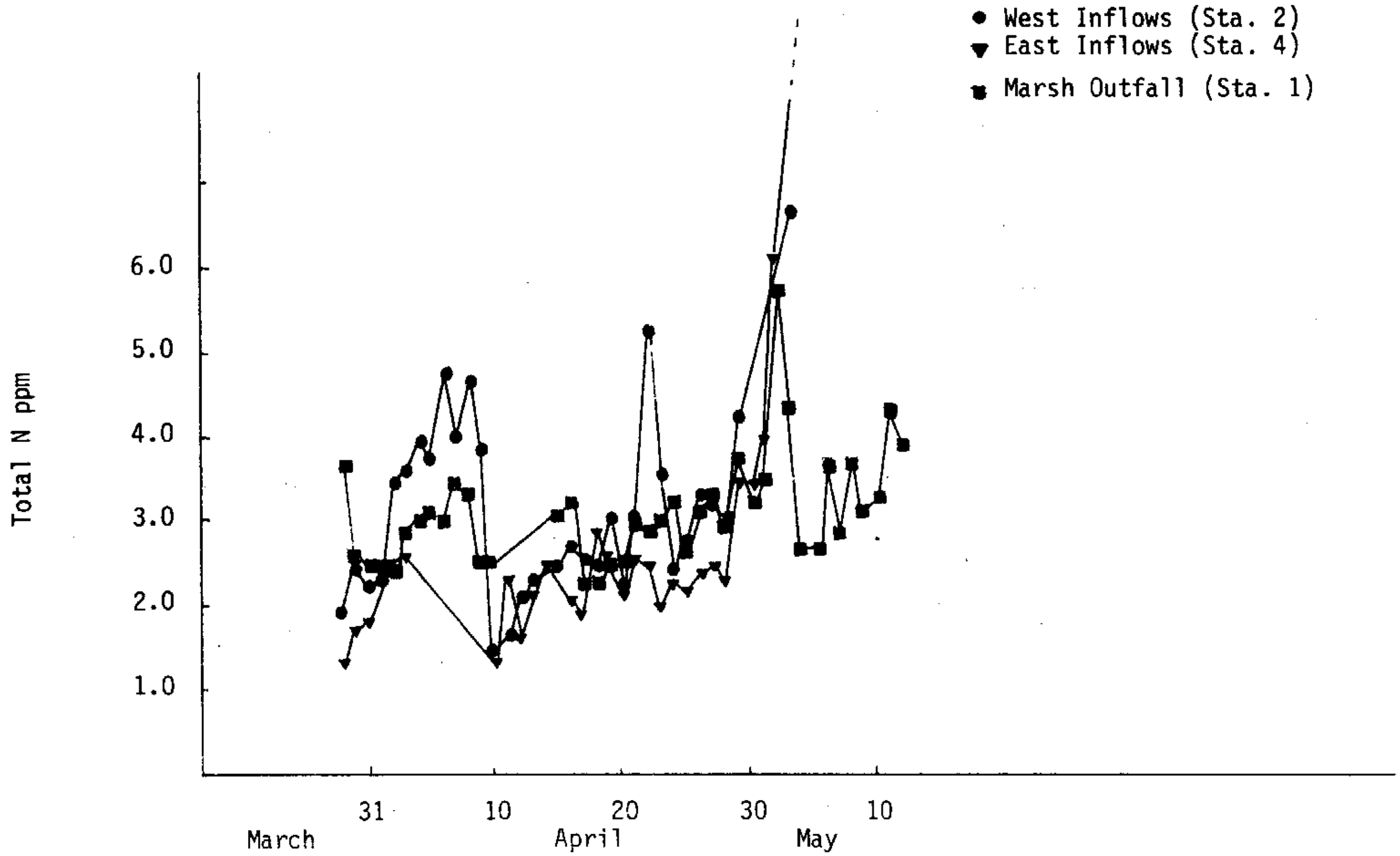


Figure VI-11. Time Series Concentrations of Total Nitrogen at the Ash Slough Wetland During Event 4 (March 29 - May 12, 1982).

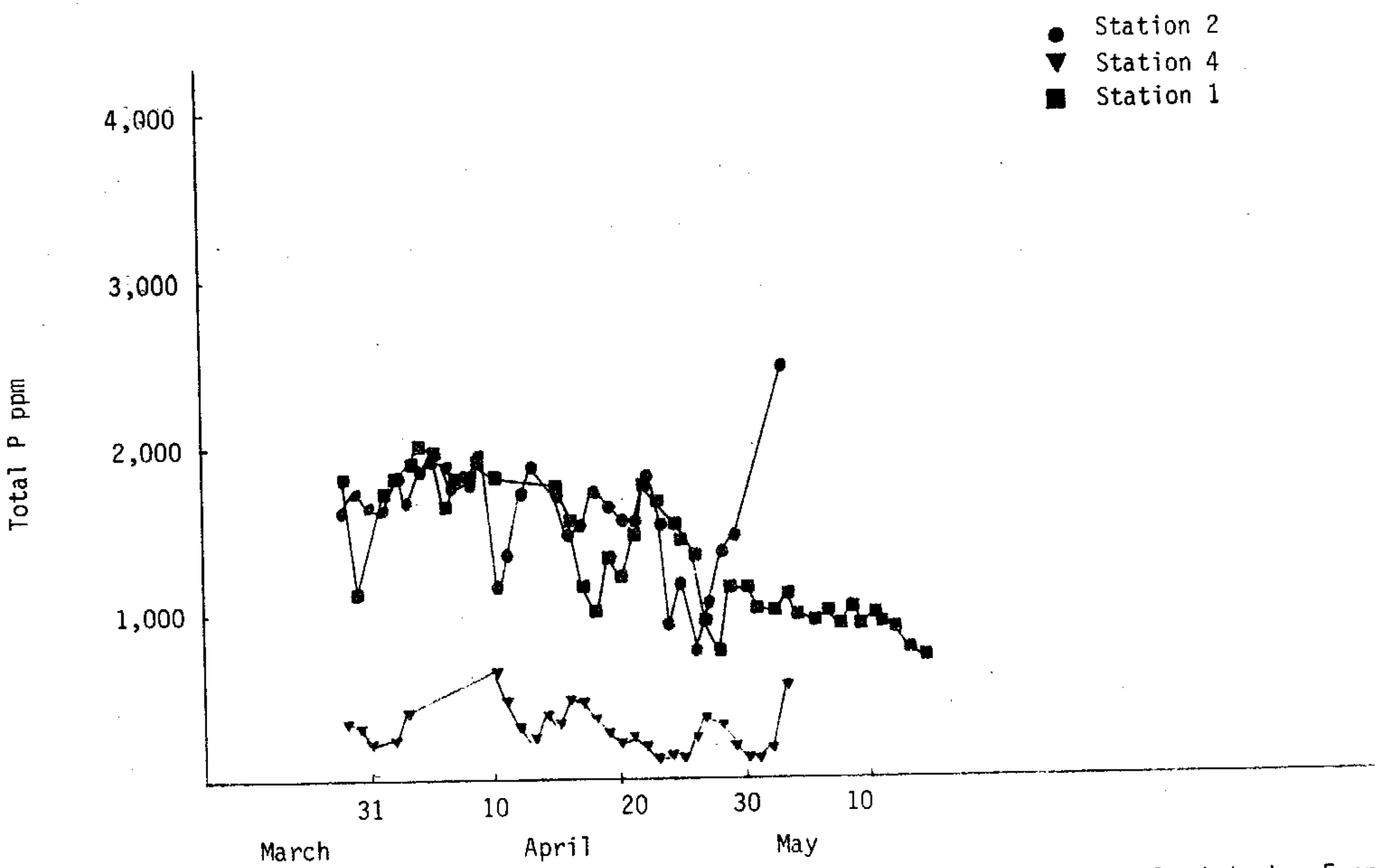


Figure VI-12. Time series concentrations of Total Phosphorus at the Ash Slough Wetland during Event #4 (March 29 - May 12, 1982).

452,000 m^3 of water was estimated to have been contributed to the marsh through both gauged and ungaged sources. Of the total, 110,905 m^3 (24.5 percent) was lost to storage, evapotranspiration, or seepage from the system.

At the same time, 21 kg of dissolved inorganic N, 79.9 kg of dissolved ortho P, and 3 kg of particulate P, or 30.9, 57.1, and 42.6 percent respectively were removed, stored, or lost in the marsh. The marsh during this event was estimated to have exported 7 kg of particulate N over the amount imported. In fact, N uptake during this period was the poorest for any of the five events. Dissolved inorganic N uptake was largely attributed to be passively associated with water loss from the system. Total measured N uptake was only 14 kg or a 1.5 percent reduction, far less than what might be expected through the water storage mechanism.

The marsh did appear to actively remove ortho P although it was relatively inefficient in uptake of particulate P (only 3 kg or 5.5 percent of the particulate P influx was removed). Total P reduction was 83 kg (almost 43 percent).

Time series inflow/discharge and nutrient concentration data for event 5 are depicted in Figures VI-13 through VI-15. The entire 1982 wet season, which was considered a single event, was actually a continual period of marsh inundation and discharge that resulted from a series of seven discrete periodic inflow events. The discharge hydrograph from the marsh reflects the inflow hydrograph at Station 2 in phase for peaks and valleys. As in each of the other events, the magnitude of the peaks at Station 1 is less than at Station 2 reflecting the fact that the discharge portion of the events is drawn out or attenuated over a longer time period and some of the water is lost in the marsh through seepage and/or evapotranspiration.

As noted previously, total N concentrations seemed to respond to periods of inflow in an inverse manner (i.e. decreasing as inflow increases) at all stations.

Concentrations at the two inflow stations were similar in both magnitude and response to increased flows. Total N concentrations at the outflow were usually higher and more variable than those noted at the inflow stations. Some of the highest total N concentrations at this site noted during the entire study were observed at the outfall station during the latter two months of this event. Total P concentrations at the Station 1 outflow again mirrored those of the Station 2 inflow. There was a tendency for concentrations to rise during the lower volume inflow/outflow periods of the event but in general, there was a slight, but steady declining trend in concentrations at both stations throughout the event. During the last part of September, concentrations of total P at Stations 1 and 2 were close to approaching the steady state background levels noted at Station 4 throughout the event.

During event 5, the marsh continued to act as a sink for phosphorus. It seemed to be in virtual equilibrium with total N, however, exporting almost as much organic particulate N as the dissolved inorganic N that it took up. The major mechanism of N and P uptake is loss of the dissolved constituents associated with water storage. Again, net uptake of particulate organic forms is inefficient.

ANNUAL WATER AND NUTRIENT BUDGETS

Though five distinct inflow/discharge events were noted during the course of this study, other rainfall and runoff events occurred that were not of sufficient magnitude to trigger surface discharge and were thus not considered as events. The rainfall and runoff of water and associated nutrients did end up in the marsh and as such were taken up and/or stored there and thus became an important and necessary factor when discussing the overall efficiency of the marsh. Therefore, water and nutrient budgets for the Ash Slough marsh were calculated on a monthly and an annual basis for each of the three years of the Upland Demonstration Project study. These data are presented in Appendix IIa. The annual budgets are summarized in Table VI-8. The budget is calculated in the same manner as described for the individual events. Estimates of loads contributed by rainfall and ungaged runoff were made using the previously described methodology.

It should be re-emphasized that during 22 months of the 36 month subject period, there was no recorded discharge from the marsh. Eighteen of those months occurred in a continuous sequence from September 1980 through February 1982. This reflected the abnormal lack of rainfall associated with the area-wide record drought that occurred in south-central Florida during that period. During that same period, the marsh was 100 percent efficient at removing all N and P from surface water merely due to the fact that all water was retained and lost through seepage into groundwater or by evapotranspiration. The drought occurred during the second year of the study and for that year the marsh was 100 percent efficient at storing both water and nutrients. During the first and third year of the study, when rainfall amounts and distribution were more nearly normal,

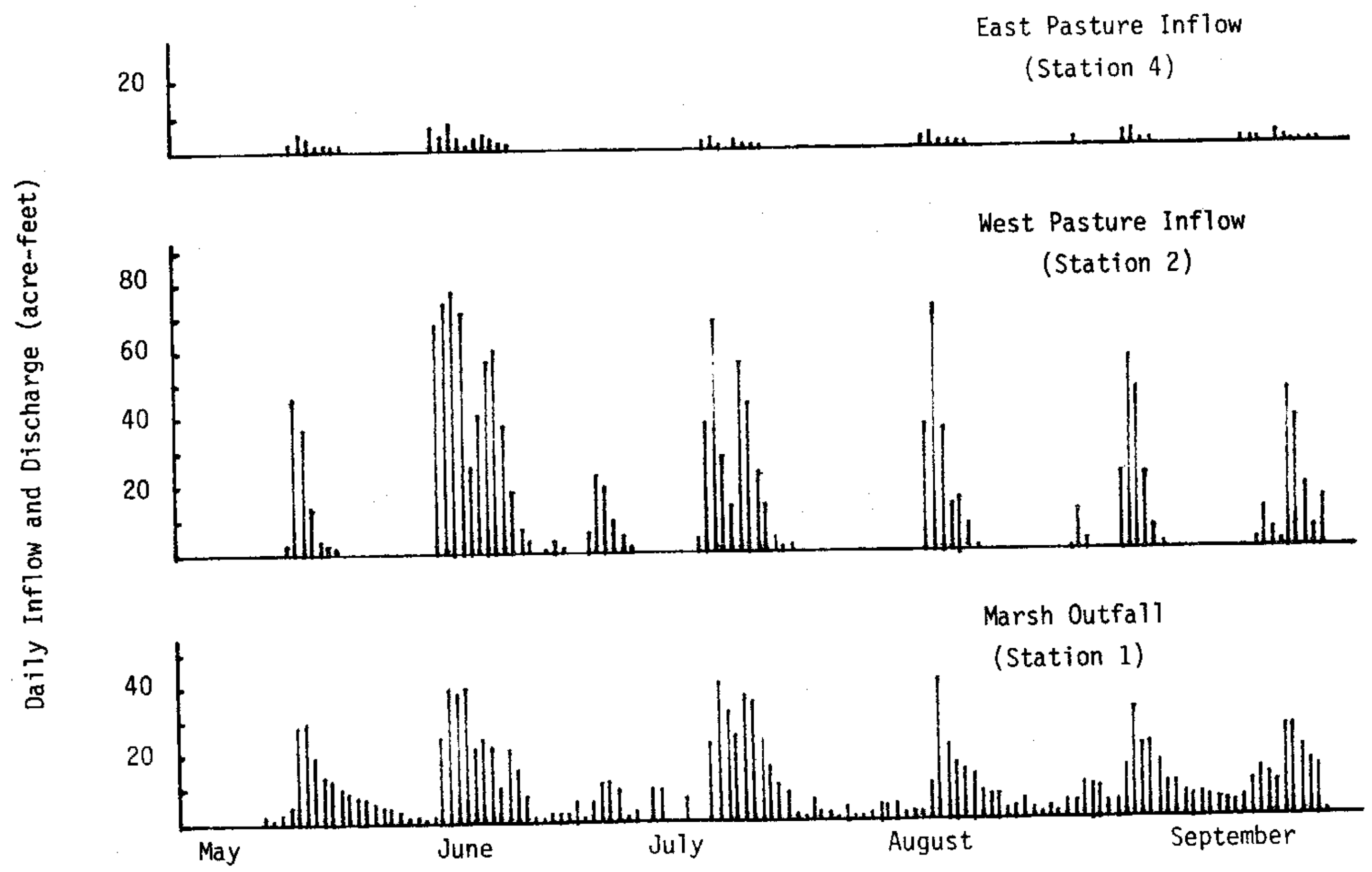


Figure VI-13. Daily Inflow and Discharge at the Ash Slough Wetland During Event #5.

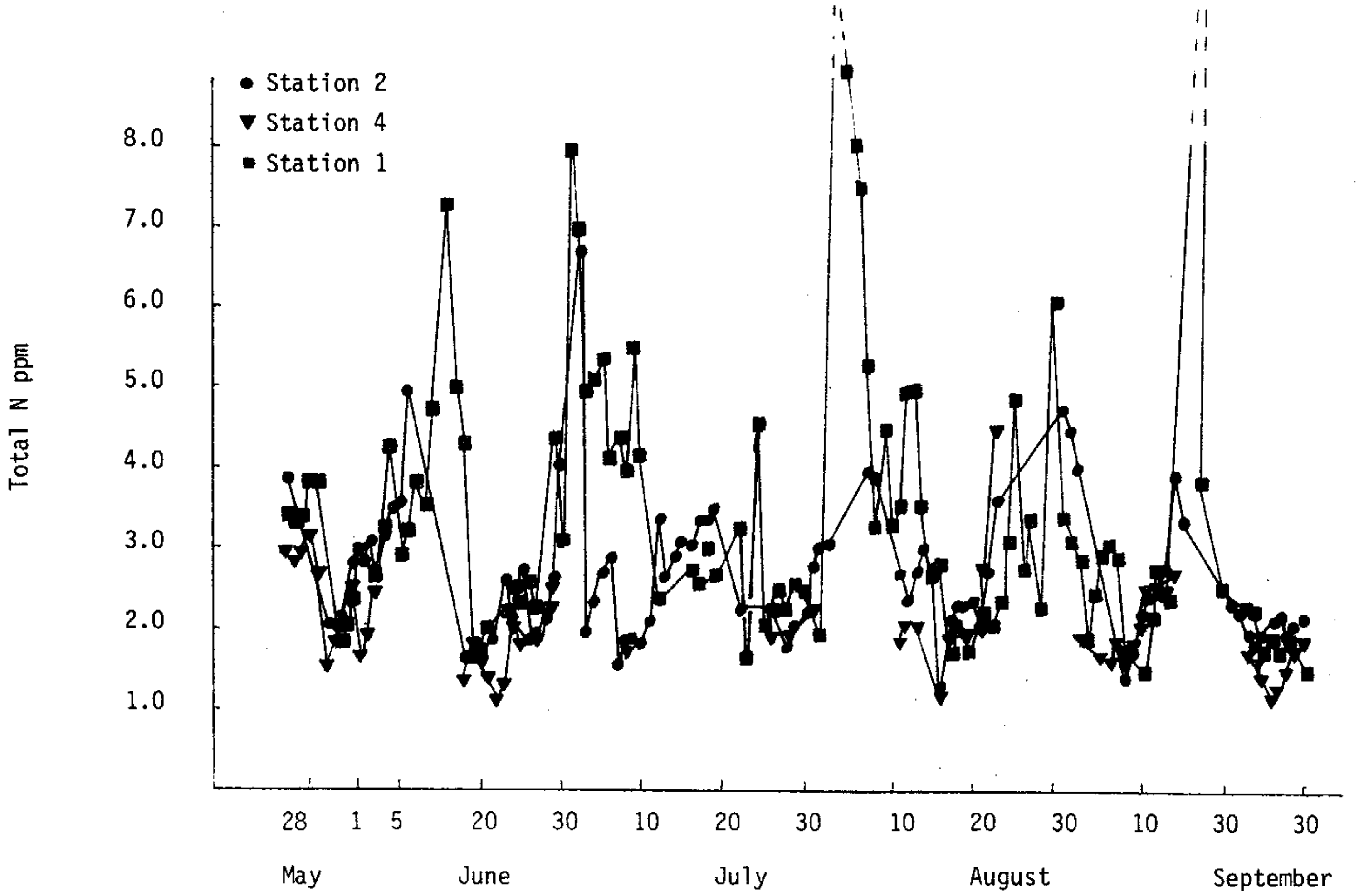


Figure VI-14. Time series concentrations of Total Nitrogen at the Ash Slough Wetland during Event #5 (May 27 - September 30, 1982).

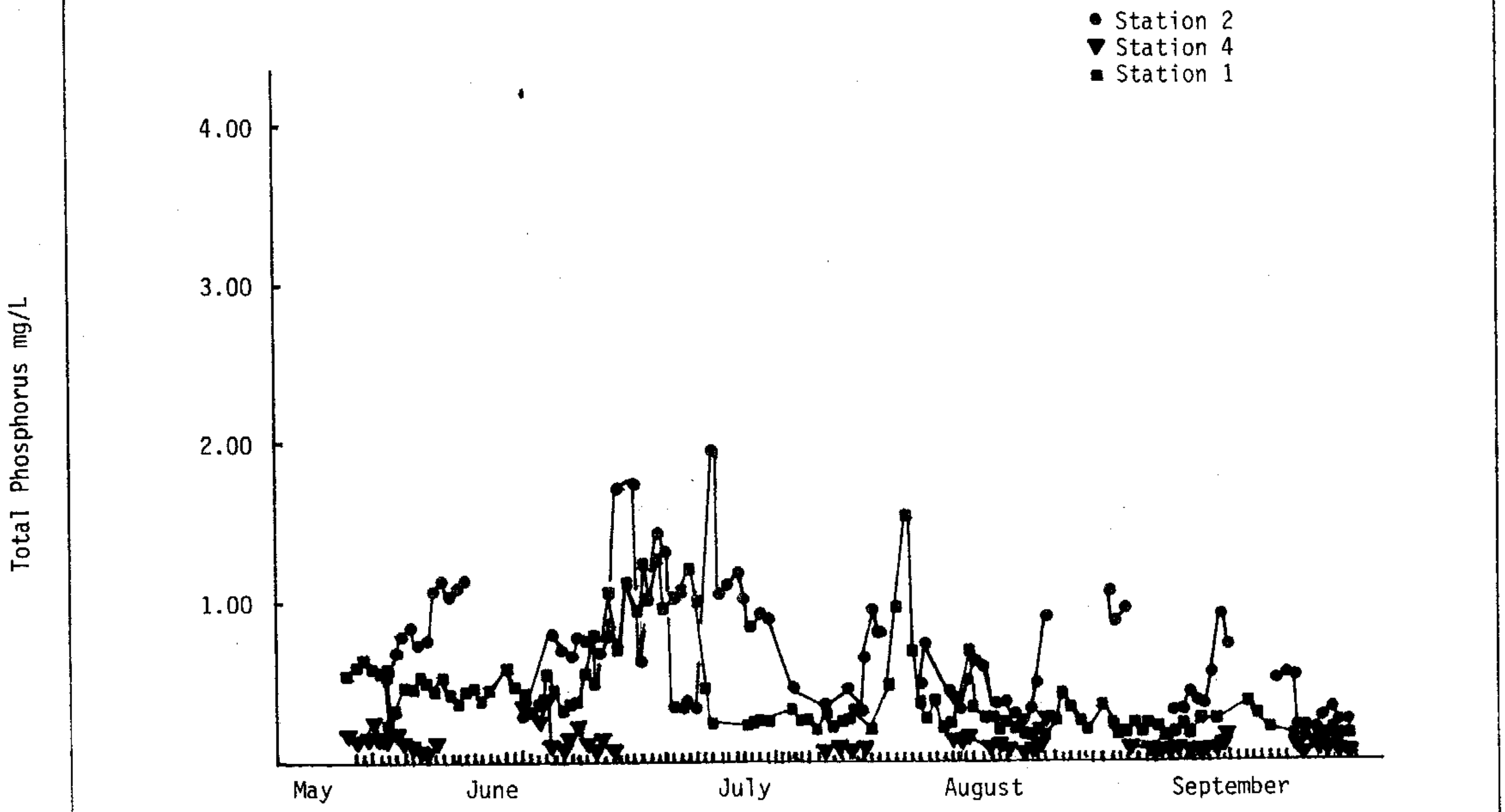


FIGURE VI-15. TIME SERIES TOTAL PHOSPHORUS CONCENTRATIONS AT THE ASH SLOUGH WETLAND DURING EVENT #5.

TABLE VI-8. ANNUAL WATER AND NUTRIENT BUDGET SUMMARY FOR ASH SLOUGH
October 1979 - September 1982

Parameter	Year	Total Contribution to Wetland	Total Discharge from Wetland	Loss (-) Uptake (+)	% Loss (-) Uptake (+)
Flow (m^3)	79-80	546,382	364,824	181,558	33.2
	80-81	58,557	0	58,557	100
	81-82	665,153	499,645	165,508	24.9
Inorganic N (kg)	79-80	89.9	16.0	73.9	82.2
	80-81	38.2	0	38.2	100
	81-82	98.6	60	38.6	39.1
Total N	79-80	1,085	782	303	27.9
	80-81	95.3	0	95.3	100
	81-82	1,426	1,374	52	3.6
Ortho P	79-80	478.9	268.0	210.9	44.0
	80-81	5.3	0	5.3	100
	81-82	408.6	247.0	161.6	39.5
Total P	79-80	563	317	246	43.7
	80-81	7.3	0	7.3	100
	81-82	488	322	166	34.1

the marsh was estimated to have absorbed and stored or lost 33.2 and 24.9 percent, respectively, of the total water inflow to the system.

Annual uptake efficiencies of water and nutrients for each year of the study are listed in Table VI-9. Annual areal nutrient loads and uptake rates for Ash Slough are plotted in Figure VI-16.

On an annual basis, nutrient uptake efficiency varies among parameters and between years. In general, however, when the percentage of water loss in the marsh is high, nutrient uptake by the marsh is higher reflecting impacts of both increased detention time and loss associated with total retention. Obviously during the drought year when no discharge occurred the marsh was 100 percent effective in removing nutrients from surface runoff. During the other two years, however, it was much less effective.

Phosphorus uptake efficiencies most closely resembled those of water loss, total uptake being roughly 10 percent greater during the two years when discharge from the marsh occurred. Ortho P loads constituted roughly 70 to 90 percent of the total P. The uptake efficiency of that fraction was slightly greater than that for the total P load indicating that either particulate P is not being removed as efficiently or there is internal cycling in the marsh such that particulate P is being released at a rate almost as fast as it is being removed.

Inorganic N is also being taken up in excess of that due to water loss/storage. Uptake efficiency was particularly good during the first year of the study but was only half as good during the final year. During these two wetter years, dissolved inorganic N made up approximately 7 to 8 percent of the total N load going into the marsh. The marsh was least effective in reducing particulate N loads. In fact, during the final

TABLE VI-9. ASH SLOUGH MARSH ANNUAL AND EVENT BASED UPTAKE EFFICIENCIES

Efficiency of Uptake Based on Annual Budgets

	Year		
	1	2	3
Total N			
Load (kg)	190.4	16.7	250.2
Uptake (kg)	53.2	16.7	9.1
% Reduction (kg)	27.9	100.0	3.6
Dissolved Inorganic N			
Load (kg)	15.8	6.7	17.3
Uptake (kg)	13.0	6.7	6.8
% Reduction	82.3	100.0	39.3
Total P			
Load (kg)	84.0	0.9	71.7
Uptake (kg)	37.0	0.9	24.3
% Reduction	44.0	100.0	39.5
Ortho P			
Load (kg)	98.8	1.3	85.6
Uptake (kg)	43.2	1.3	29.2
% Reduction	43.7	100.0	34.1
Flow (m^3)			
Load (kg)	546,382	58,557	665,153
Uptake (kg)	181,558	58,557	165,508
% Reduction	33.2	100.0	24.9

Efficiency of Uptake Based on Events
Percent

	Water	Inorganic N	Total N	Ortho P	Total P
Event 1	30.0	78.4	29.0	39.3	41.0
Event 2	82.8	92.5	85.1	82.7	82.8
Event 3	25.8	84.0	13.7	38.7	36.9
Event 4	24.1	34.4	6.3	305	28.6
Event 5	24.5	20.9	1.5	57.1	42.6

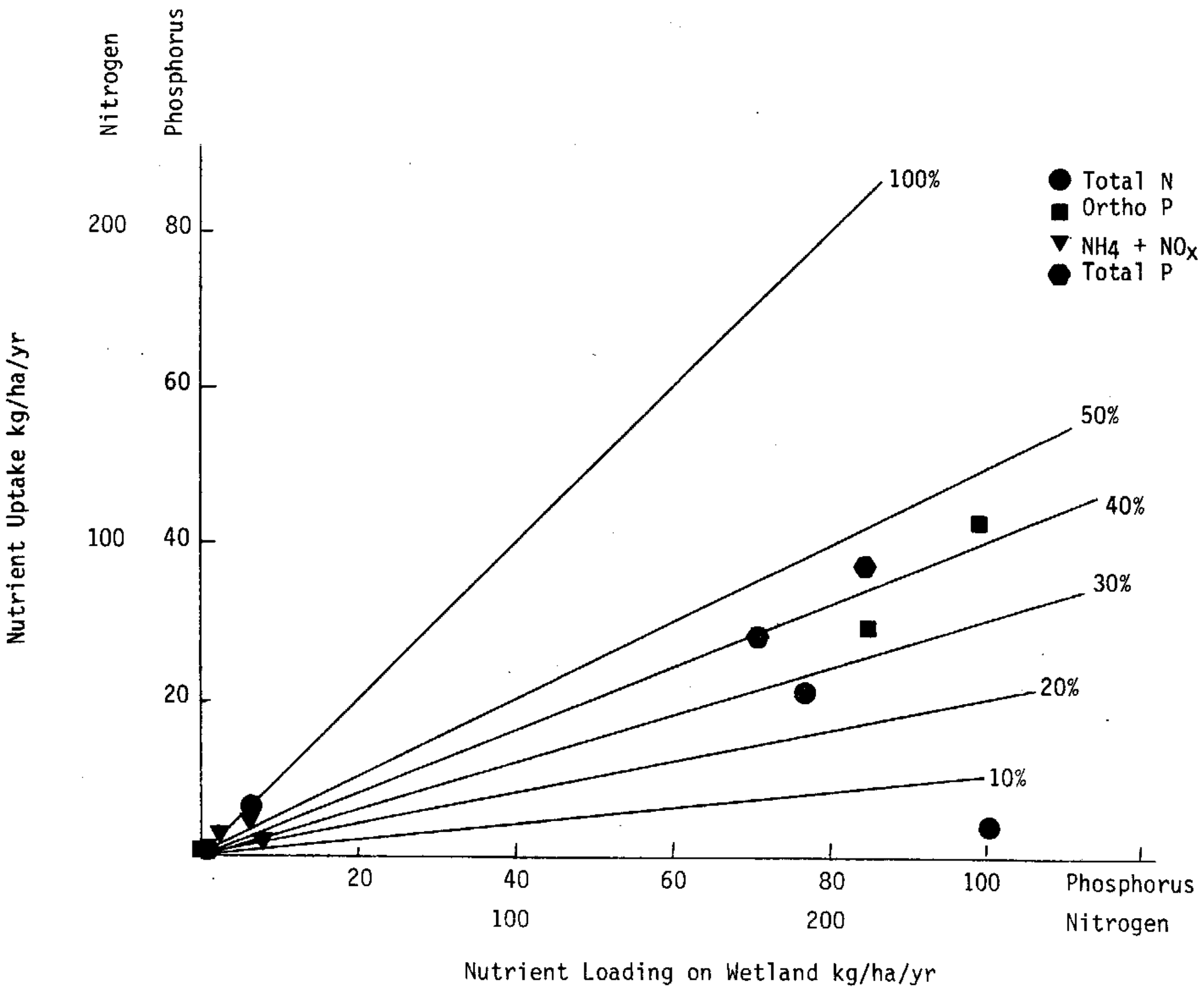


Figure VI-16. Loading, Uptake, and Uptake Efficiencies for Nitrogen and Phosphorus in the Ash Slough Detention/Retention Wetland.

year of the study, total N uptake was negligible and could be attributed almost entirely to the uptake of the dissolved inorganic N load.

On the basis of these data, the following conclusions can be drawn about the efficiency and method of function for nutrient removal in the Ash Slough marsh:

1. Calculated on both an annual and an event basis, the Ash Slough marsh functioned as a net sink for both nitrogen and phosphorus.

2. On both an annual and an event basis, the marsh served as a water loss/storage reservoir and thus attenuated flow volumes at the discharge.

3. Efficiencies of N and P uptake were generally slightly higher than noted for individual events when calculated on an annual basis, but in either case, nutrient uptake efficiency was usually only slightly greater than the percent attenuation in flow volume through the marsh. Therefore, the major fraction of nutrient loss in the system (particularly dissolved forms such as ortho P and inorganic N) could be attributed to loss of water from the system.

4. Of the nutrient species of interest, dissolved inorganic N was consistently taken up most efficiently, but also was the nutrient species of least quantity in annual loads.

5. Total N, largely in particulate form (60-94 percent), was the parameter least efficiently taken up. It was also the nutrient that was contributed to the marsh in the largest quantities. The marsh appears to be close to near steady state equilibrium with regards to the total N flux through the system.

6. Both ortho and total P loads appear to be reduced roughly 10 percent in excess of percentage of flow volume attenuation. This appears to be fairly consistent for the two years of "normal" rainfall/runoff through the marsh system. This would seem to indicate that the marsh functions as a slightly active uptake site for P, but then again, the major fraction of loss can be attributed to passive uptake. (i.e. removal of the dissolved constituents associated with water loss or storage).

ARMSTRONG SLOUGH

One of the KRVCC's goals for the Upland Demonstration Project was to evaluate the feasibility of the biological and water quality impacts that occur by re-establishing wetlands in what were originally Kissimmee River floodplain backwater marshes. A 30 acre (12.1 ha) portion of the Armstrong Slough watershed was selected for the restoration and monitoring effort. Prior to construction activities, a portion of the site receiving inflow from the southern tributary could already be characterized as a flow-through marsh. Flow from the northern tributary, conveyed directly to the Kissimmee River via a dug channel, was not subject to interaction with any wetland system. The banks of the channel were elevated with the spoil remains left from when the channel was originally dug. On the north side of this channel the spoil served to impede the flow of surface runoff and thus created an intermittently wet perched water table marsh area that, under normal circumstances, had no means of surface interaction with water in the main channel. During April and May of 1980, the SFWMD altered the physical and hydrological characteristics of the site such that the main channel was completely blocked and water entering via both the northern and southern tributaries was forced from the respective channels into the existing flow-through and/or perched water table wetlands. The net result was the conversion of the entire area into a flow-through wetland the configuration of which is depicted in Figure II-5.

A comparison of water quality parameters in both pre-and post restoration states was accomplished by biweekly monitoring before the restoration of the flow-through system (October 1979 - May 1980) and thereafter.

Once restoration was completed, the marsh covered a permanent surface area of approximately 12.1 ha. It received and passed through surface runoff from a contributing watershed of over 4,000 ha.

Soil types predominant in the marsh as described by Readle (1979) and Krottje, et. al. (1981) were Samsula muck in the central portion, surrounded by a zone of Placid fine sand, and finally Basinger fine sand at the periphery. These are all acid soils with an organic content ranging from 10.7 percent for the Basinger fine sand at the periphery to 40.4 percent for the Samsula muck.

Climatic conditions during the study period have been described previously (Section IV). During the three year subject period the wetland was continually inundated. With a few exceptions measurable discharge from the wetland via the discharge culverts was minimal to non-existent for a prolonged period during the drought (January-July, 1981). Flow into the marsh, however, was always noted from the northern tributary channel. In addition to rainfall runoff, this is thought to be contributed by discharge or loss of groundwater used for citrus irrigation at the head of the watershed. Flow in the southern tributary channel, on the other hand, was of intermittent nature, occurring only in periods during and following significant amounts of rainfall. During the drought, the channel was devoid of standing water for periods up to three months duration.

METHODS:

Gauged inflows as well as N and P loads into the marsh from the contributing watersheds were measured at Stations 2 and 3 in the north and south tributaries respectively. Flow and loadings from rainfall and runoff in the ungauged area around the marsh (232 ha) and on the marsh (12.1 ha) itself were estimated using daily rainfall measurements collected at a USGS recording rainfall gauge located on the northern tributary watershed. Estimates of rainfall contributions to the nutrient and water budgets were made using basically the same rationale and methodology applied to the Ash Slough marsh. The primary difference was the choice of runoff coefficient to apply to the ungauged watershed surface area on the periphery of the marsh. To estimate this coefficient, the measured runoff/rainfall volume ratio of the southern tributary watershed for each of the three years of the study was applied to the total rainfall on the ungauged watershed for that year to arrive at an estimated volume reaching the marsh. These ratios were 11.3, 19.8, and 68.3 percent respectively. The runoff/total rainfall ratios of the northern watershed were ignored since additional contributions to the water budget from irrigation activities invalidated runoff estimates using this methodology.

No provisions were made for estimating water loss through either seepage or evapotranspiration. These components of the water budget were thus included as part of the overall uptake/storage/export efficiency calculated for the wetland. Subsurface losses and gains are potentially considerable given the nature of the porous and permeable surface soils in and around the Armstrong Slough wetland. This obviously can impact calculated water and nutrient budgets (particularly dissolved) as it is impossible to determine what quantities of uptake or export are attributable to the marsh and what quantities are attributable to groundwater interaction.

TIME SERIES DATA:

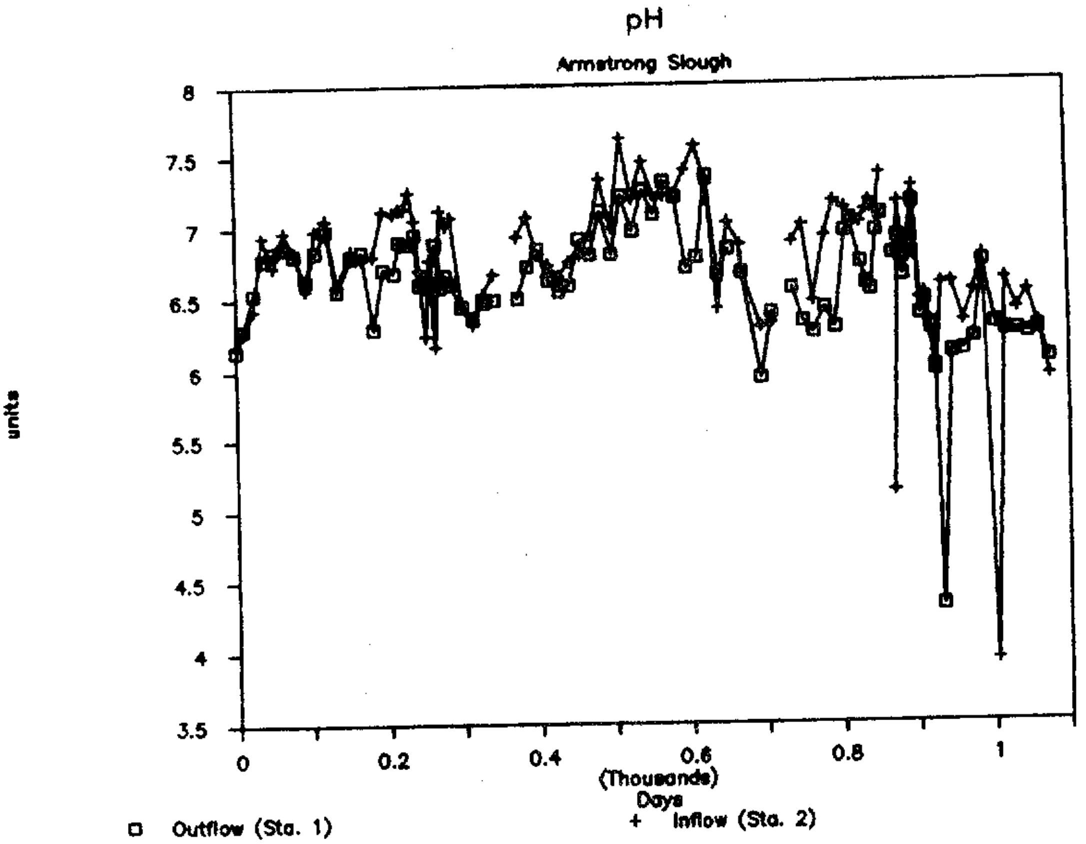
Time series data for the subject study period of record are depicted in Figures VI-17 through VI-20. During the study three events occurred which caused notable impacts in some or all of the monitored water quality parameters. These events were: 1) the May 1980 construction of an earthen plug to block the main channel and subsequently restore the marsh to a flow-through system, 2) the record drought of 1980-81, and 3) a hard freeze that occurred in February 1982.

Construction activities during May of 1980 were identified as the reason for a marked increase in turbidity at Station 1 during this period. Turbidity loads in the south tributary also increased due to concomitant reconstruction of the concrete flume used for flow measurements at Station 3. Turbidity levels at Station 2 in the north tributary, upstream of the construction activity, remained low and unaffected by the these events. In general, turbidity levels at the marsh outfall were continually low (less than 3 NTU's). Turbidity was continually low at the two inflow stations, usually less than 5 NTU's. A brief period of slightly increased turbidity in the north channel inflow occurred in April 1982. Turbidity at the marsh outfall responded accordingly with the peak levels being slightly out of phase and of slightly less magnitude that those noted in the north channel. This coincided with a period of rainfall, subsequent runoff, and increased flow through the marsh that began the 1982 wet season. It is of interest to note that turbidity levels were not impacted at all by the first flush event of the previous year following the prolonged drought. This marsh, it can be concluded, does not seem to consistently or effectively remove the low level turbidity associated with increased flows.

Like turbidity, pH levels in the marsh more closely reflected those noted in the northern tributary. These were relatively constant and remained neutral to slightly acidic with no obvious trends or responses to major events such as either the first flush or the freeze.

Color levels at the marsh outflow again reflected those measured in the north tributary. Peaks and valleys were in phase and of similar magnitude. The marsh appeared to have no impact on either enhancing or removing color intensity.

Like the other physical parameters, specific conductance at the outfall was influenced primarily by inflow from the northern tributary. During periods of high flows through the marsh, peaks and valleys are in phase and of similar magnitudes. During the low flow months of the 1980-81 drought, conductivity at the marsh outfall was generally less than that measured in the northern tributary. Seasonal trends in conductivity levels (i.e. peaks during low flow months, etc.) in the northern tributary were similar at the marsh outfall.



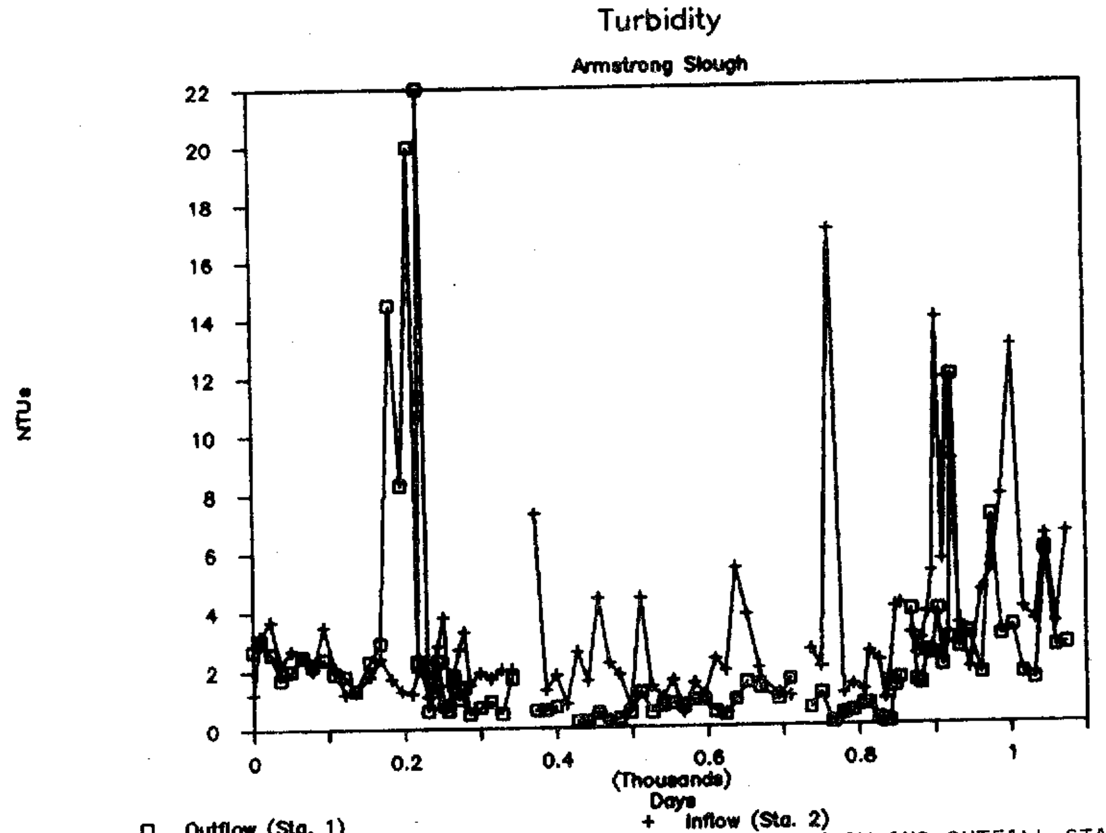
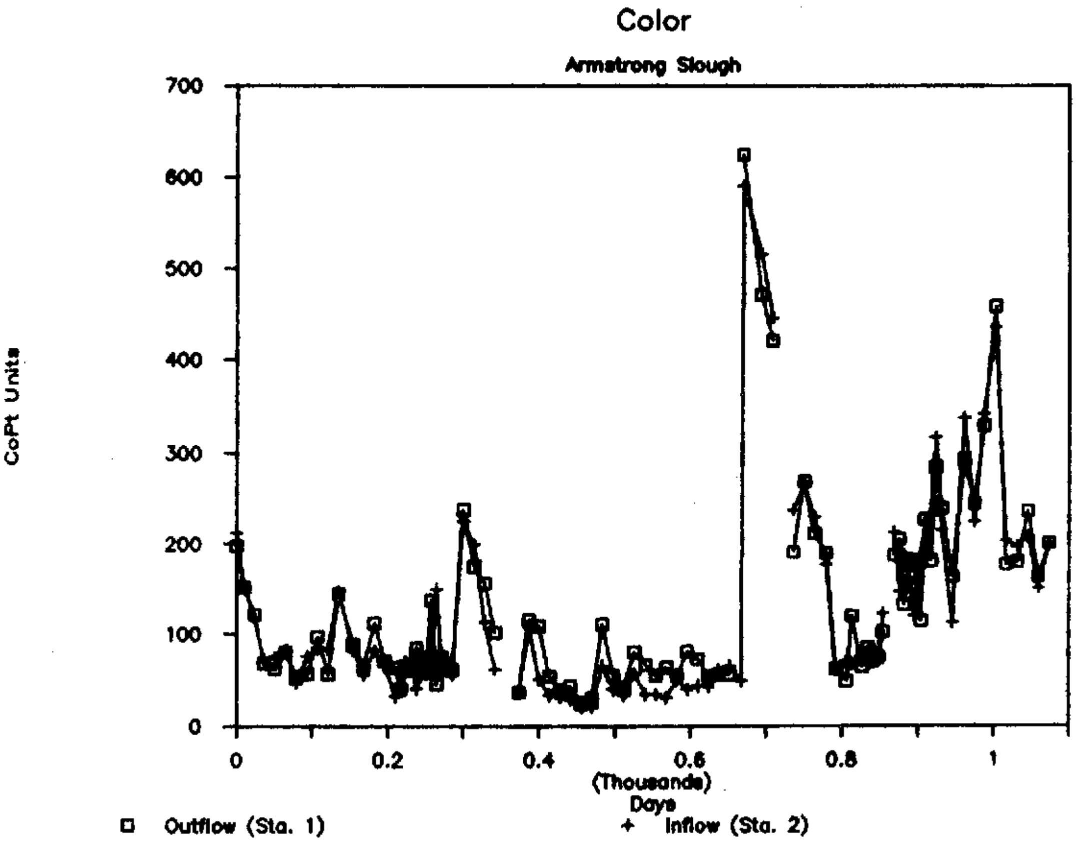


FIGURE IV-17. TIME SERIES CONCENTRATIONS AT MAJOR INFLOW AND OUTFALL STATIONS IN THE ARMSTRONG SLOUGH WETLAND. . .pH AND TURBIDITY.



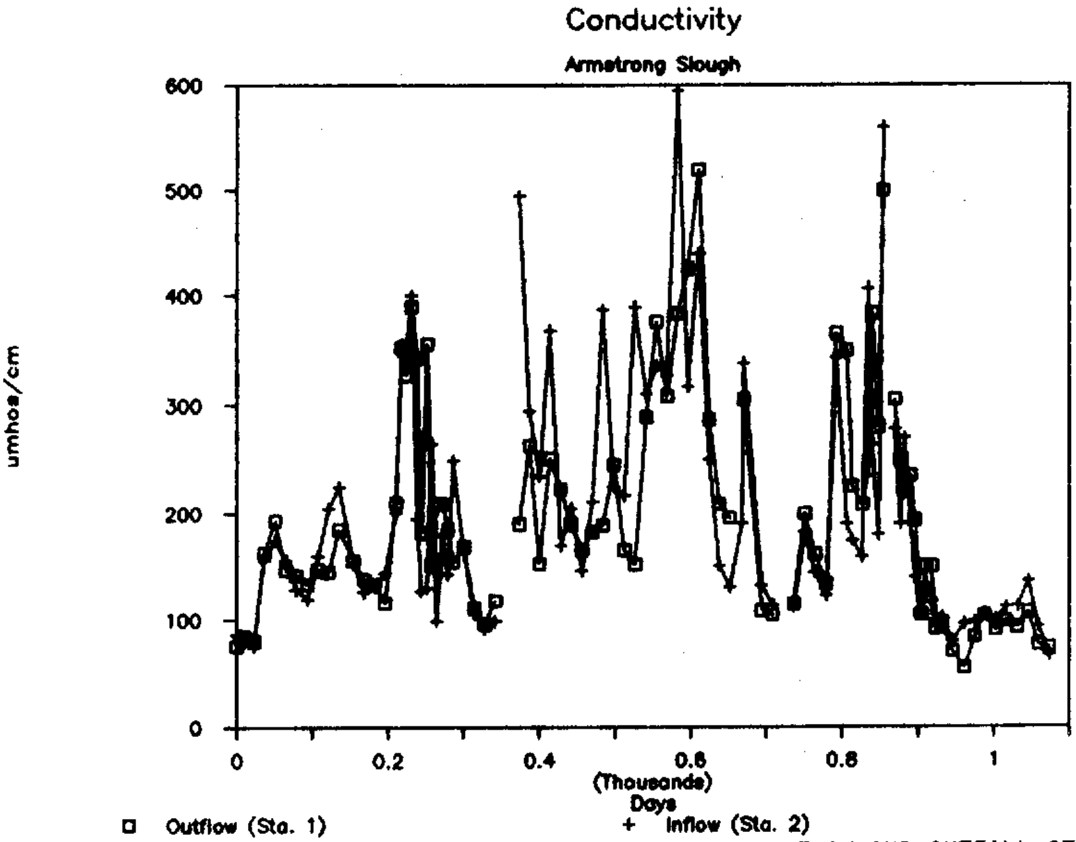
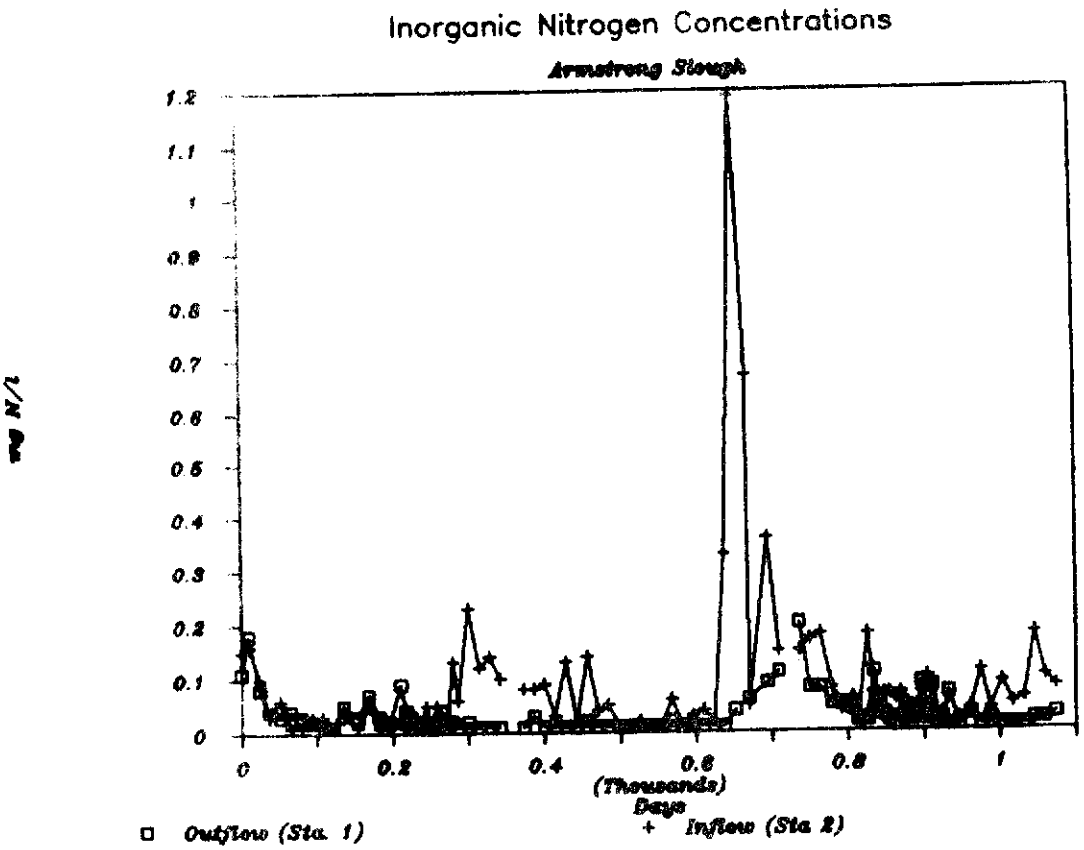


FIGURE VI-18. TIME SERIES CONCENTRATIONS AT MAJOR INFLOW AND OUTFALL STATIONS IN THE ARMSTRONG SLOUGH WETLAND. . .COLOR AND CONDUCTIVITY.



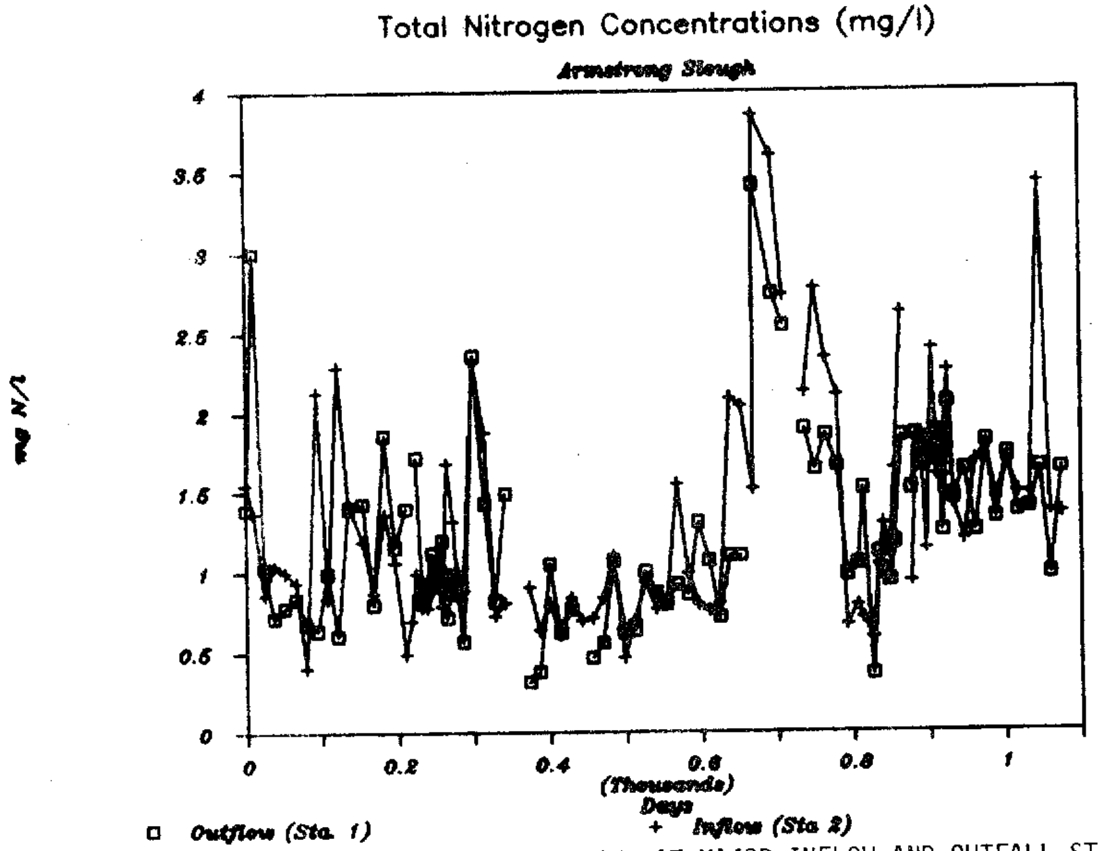
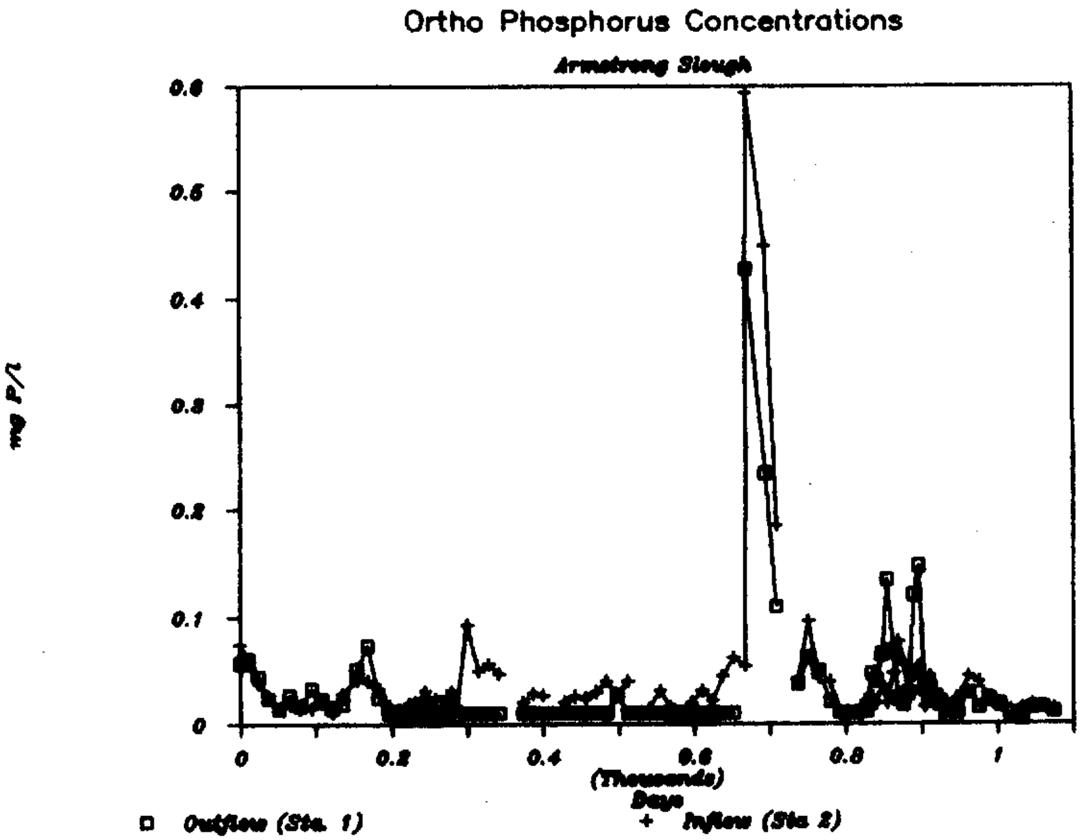


FIGURE IV-19. TIME SERIES CONCENTRATIONS AT MAJOR INFLOW AND OUTFALL STATIONS IN THE ARMSTRONG SLOUGH WETLAND. . .INORGANIC AND TOTAL NITROGEN



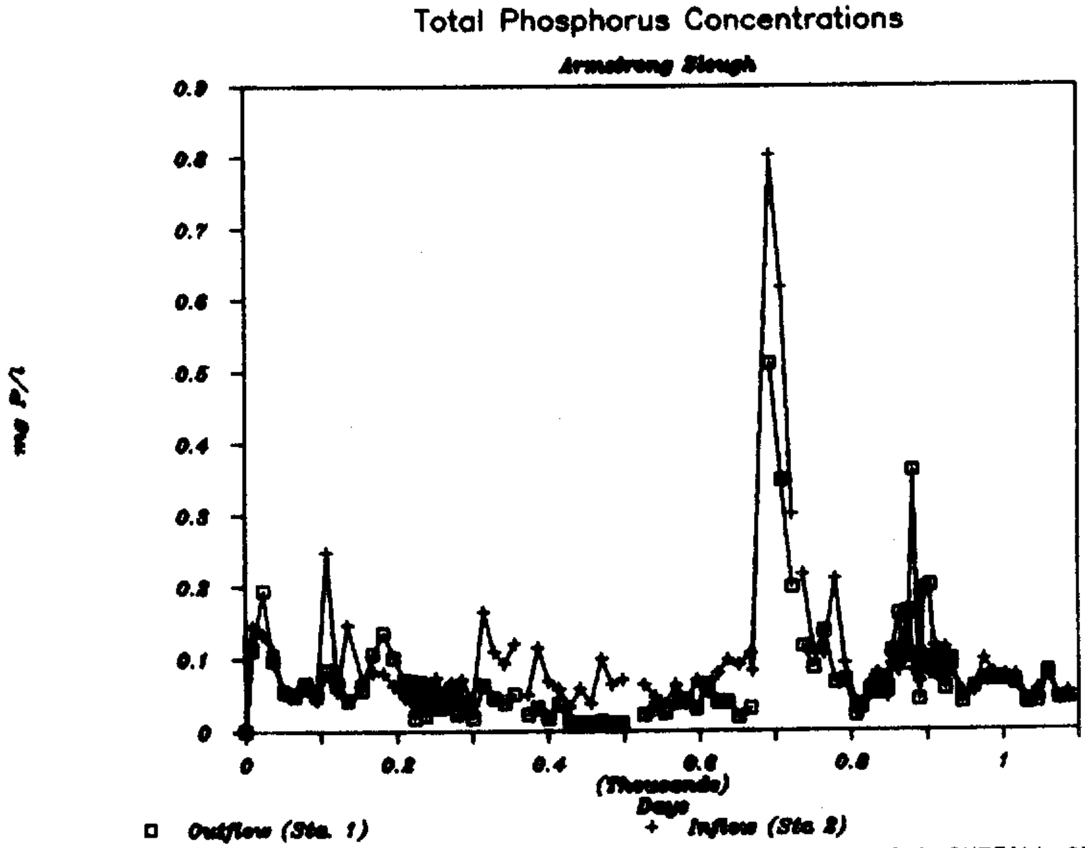


FIGURE IV-20. TIME SERIES CONCENTRATIONS AT MAJOR INFLOWS AND OUTFALL STATIONS IN THE ARMSTRONG SLOUGH WETLAND. . .ORTHO AND TOTAL PHOSPHORUS.

In conclusion, the marsh did little, if any, to alter concentrations of the physical parameters of interest. Trends and magnitudes at the site outfall reflected those noted in the northern tributary which was the largest single contributor of flow.

Peaks and valleys in total nitrogen concentrations at the marsh outfall are in phase with and of similar magnitude to total N concentrations measured in the northern tributary channel. The concentrations leaving the marsh thus reflect the same trends, that is they increase during periods of high discharge and decrease during periods of low discharge.

Inorganic N concentrations in the inflow tributaries were generally low and usually far less than one-tenth of the total N concentration. Pulses of inorganic N at the marsh outfall occurred during the first flush event and following the 1982 freeze. These pulses at the marsh outfall reflected similar pulses in the two inflow tributaries, but the peaks had been somewhat attenuated. Variability of inorganic N concentrations appeared to be less after passage through the marsh.

Total and ortho P concentrations followed the same general pattern; however, after conversion of the area to the flow-through marsh, peak P concentrations at the outfall were attenuated to levels less than those noted in the contributing tributaries. Two events did have impacts on both ortho and total P concentrations. During the first flush event of August 1981, total and ortho P concentrations at the marsh outfall increased significantly, but concentrations of these species remained less than those in the north tributary channel.

The second event that affected P concentrations in outflow from the marsh was the hard freeze that occurred in February 1982. Following this event there was a marked increase in particulate P concentrations at the outfall which were not attributable solely to increases in concentrations in either the major contributing tributaries. While concentrations of total P in the north channel did increase, they were generally only about half of the peak concentrations measured at the marsh outfall. The other unconventional characteristic of this event was that the flux of P from the marsh was largely in a particulate form. The predominant species during the first flush peak was dissolved ortho P.

MASS LOADINGS AND UPTAKE:

Water and nutrient mass loading budgets were calculated on an annual basis from October 1 through September 30 for each of three consecutive years from 1979 through 1982. The budgets were calculated using the following equation:

$$Q_{North} + Q_{South} + R + U - Q_{Out} = \text{Uptake/Export}$$

Where:
- Q_{North} = Inflow from north tributary
- Q_{South} = Inflow from south tributary
- R = Rainfall on marsh
- U = Ungauged runoff
- Q_{Out} = Outflow from the marsh

During the three years of the study, the northern tributary watershed was the primary source of flow contributing 81.6, 75.6, and 56.7 percent of the total flow to the marsh on an annual basis. The south tributary contributed 13.8, 18.9, and 34.7 percent of the flow respectively for each of the three years. Direct rainfall contributed 1.5 percent or less each year and runoff from the ungauged watershed ranged from 3.1 to 8.0 percent of the total flow on an annual basis. The preponderance of flow contributions from the north tributary is the reason why time series concentrations of physical and chemical parameters at the marsh outfall correspond so closely to those in the north tributary, especially during periods of higher flows. If one assumes the surface area of the marsh remains relatively constant at 12.1 ha, and an average depth of water in the marsh of 2.0 feet (0.61 m), then annual mean residence time of water in the marsh for the three years of the study would range from 1 to 3.5 days. Assuming an average water depth of 3.0 feet (0.91 m) then annual mean residence times would range from 1.4 to 5.2 days. Of course the marsh surface area does not remain constant as stages rise and fall; however, the comparatively steeper slopes of the land on either side of the marsh restrict the extent of areal surface at the water stage elevations commonly encountered during the study. For purposes of grossly estimating typical detention times the significance of the error is not very important. Table VI-10 lists monthly and annual flows into the marsh and expected mean retention times at mean depths of 2.0 and 3.0 feet. These figures should in no way be taken as absolutes. They do, however, provide insight into the general magnitude and range of time that water parcels have opportunity to interact within the marsh and thus be subject to treatment. Mean estimated theoretical residence times on a monthly basis range from as little as 0.3 days up to 34.4 days. Higher flows naturally resulted in shorter detention times and, therefore, less time for treatment.

During the three years of this study, the calculated marsh water budget ranged from 58.6 percent water loss/storage to excess export from the marsh of 9.4 percent (Table VI-11). Given the nature

TABLE VI-10. ARMSTRONG SLOUGH MARSH ESTIMATED MEAN MONTHLY AND ANNUAL DETENTION TIMES (DAYS) WITH DEPTH

Month	Total Flow In (m^3)	Detention Time at 2' Mean Depth	Detention Time at 3' Mean Depth
1979-80			
October	4,315,430	0.5	0.8
November	202,925	11.1	16.7
December	188,579	11.9	18.2
January	146,949	15.5	23.8
February	447,437	4.6	6.8
March	394,325	5.8	8.6
April	213,884	10.3	15.8
May	261,725	8.9	12.9
June	147,248	15.0	23.1
July	206,480	11.1	16.3
August	862,535	2.6	4.0
September	304,331	7.3	10.7
TOTAL	7,691,953	3.5*	5.2*
1980-81			
October	134,186	17.2	25.8
November	179,403	12.9	18.8
December	149,255	15.5	22.1
January	126,723	18.2	25.8
February	302,755	6.8	10.4
March	174,819	12.9	19.4
April	152,928	14.3	21.4
May	160,578	14.1	20.7
June	206,160	10.7	15.8
July	113,697	20.7	31.0
August	1,707,570	1.3	2.0
September	6,779,565	0.3	0.5
TOTAL	10,175,053	2.6*	4.0*
1981-82			
October	464,801	4.9	7.4
November	432,147	5.3	7.7
December	94,693	23.8	34.4
January	160,792	14.1	20.7
February	354,945	5.8	8.8
March	635,247	3.6	5.3
April	2,165,107	1.0	1.5
May	1,172,701	1.9	2.9
June	6,940,955	0.3	0.5
July	3,251,541	0.7	1.1
August	4,062,019	0.6	0.8
September	8,303,083	0.3	0.4
TOTAL	28,046,032	1.0*	1.4*

*Estimated Mean Annual Detention Time

of the accuracy of the flow measurement devices and the land surface and seasonal rainfall distribution during the study, a water budget that seems to result in more water leaving the marsh than enters via surface flow is within the realm of possibility. Under ideal conditions accuracy of flow measurements at the flume is estimated to be ± 5.0 percent, accuracy of the open channel measurements is ± 20.0 percent, and accuracy of culvert measurements is ± 15.0 percent. In addition, the land slope on the 232 ha ungauged watershed on either side of the marsh is relatively steep. Given the porous nature of the soil and the downhill slope towards the marsh, continuously saturated soil conditions during a particularly long or intense wet season, such as occurred in 1982, could have resulted in contributions of some unmeasurable quantities of groundwater seepage into the marsh from the shallow subsurface flows. These would manifest themselves in the water budget as decreased efficiency of uptake/storage and even as export of water from the marsh in excess of measured inflow from surface water sources. The apparent export of water from the marsh during the 1981-82 year could be attributed to either or both of these causes. In any event, the marsh was the most effective water sink during the first year of the study (58.6 percent storage/uptake), less effective during the second year (29.9 percent storage/uptake), and was ineffective during the final year when it was calculated to have exported 9.4 percent more water than could be attributed to measurable or estimated surface inflow.

During the study the marsh continually acted as a sink for dissolved inorganic N. Annual efficiencies ranged from 86 percent to 50.8 percent. As previously described, where percent nutrient uptake is equal to or less than percent water storage/loss, then uptake is considered of a passive nature. Where percent nutrient uptake exceeds percent water storage/loss then some of the uptake is probably due to active adsorption,

TABLE VI-11. ARMSTRONG SLOUGH UPTAKE EFFICIENCIES (kg/ha) (year)

	Load	Uptake	% Reduction
Flow (m^3)			
Year 1	7,691,953	4,505,426	58.6
Year 2	10,175,053	3,045,921	29.9
Year 3	28,046,032	-2,633,757	-9.4
Total N			
Year 1	973	634	65.2
Year 2	2,151	688	32.0
Year 3	3,578	-187	-5.2
Dissolved Inorganic N			
Year 1	56.7	48.8	86.0
Year 2	143.3	93.9	65.6
Year 3	129.5	65.7	50.8
Ortho P			
Year 1	34.9	29.0	83.3
Year 2	191.0	79.7	41.7
Year 3	52.9	1.9	3.6
Total P			
Year 1	79.2	62.7	79.2
Year 2	282.1	121.3	43.0
Year 3	128.9	-32.3	-25.1

assimilation, or alteration mechanisms. In the case of dissolved inorganic N the percent uptake during each year exceeds that expected by passive loss alone. In fact, during the final year of the study when the surface outflow of water from the marsh exceeded the surface inflow, the marsh still removed over 50 percent of the dissolved inorganic N in the surface waters. The dissolved inorganic N was the minor fraction of the total N load ranging from 3.6 to 6.7 percent of the total N load in the inflow to the marsh. In any event, mechanisms (probably nitrification-denitrification) existed that resulted in active uptake.

The marsh was less efficient in active removal of particulate N, being only 5.3 percent more efficient during the first year of the study than what would be attributed to passive uptake alone. Little or no active uptake occurred during the next year, and only 2.1 percent uptake was noted during the last year. On an annual basis, total N uptake efficiencies over that expected from passive loss through water loss/storage was 6.6, 2.1, and 4.2 percent, respectively.

Trends in ortho and particulate P uptakes were similar to those described for nitrogen. Ortho P was taken up at efficiencies that exceeded those expected from passive mechanisms alone. The marsh functioned as an ortho P sink even during the third year of the study when measured surface outflow exceeded surface inflow. Ortho P constituted roughly 40 to 70 percent of the total P load entering the marsh, and about 31-70 percent of the total P load leaving the marsh. Annual reduction in the ortho P load ranged from a high of 956.6 kg (41.7 percent of the inflow load) during the drought year to 22.8 kg (3.6 percent of the inflow load) during the last year of the study. Uptake efficiency was greatest (83.3 percent) during the first year of the study when 347.2 kg of ortho P was taken up by the marsh.

Total P loads followed the same annual trends described for ortho P. Deleting the dissolved ortho P fraction from the total P load, the remaining particulate P removal efficiencies and actual load removal trends were unaffected. Four hundred and ninety-nine kilograms (45.6 percent) of particulate P were removed by the marsh during the drought year. Maximum uptake efficiency was 75.9 percent when 404 kilograms were removed during the first year of the study. The marsh, however, was responsible for export of 410 kg of particulate P over that measured coming in by surface flows during the final year of the study. Overall calculated total P load removal efficiency of the marsh was 79.2 percent during the first year, 43.0 percent during the second, and export of 25.1 percent more than surface inflow loads during the third year.

COMPARISON OF ASH AND ARMSTRONG SLOUGH DETENTION/RETENTION WETLANDS

As previously described, the Ash and Armstrong Slough Wetlands were significantly different from each other in terms of the type of hydrologic regime that characterized each. In other ways, however, there were similarities. Wetland vegetation species such as maidencane (Panicum hemitomon), bluestem (Andropogon spp.), St. John's wort (Hypericum spp), and pickerelweed (Pontederia spp) dominated at Ash Slough and soft rush (Juncus offusus), southern watergrass (Hydrocloa caroliniensis), sedges (Scirpus, spp) and St. John's wort were prevalent species at Armstrong Slough (Hunters, 1980). The adjacent lands and contributing watersheds at each site were predominantly improved pasture used for grazing beef cattle. Differences in the contributing watersheds were in cattle stocking densities, fertilizer application practices, drainage ditch density, and topographic relief in the area immediately adjacent to the marsh.

Water depth in the wetlands was somewhat variable; however, the Ash Slough marsh was the only one to experience the extreme condition of complete dehydration. This occurred for a prolonged period during the 1980-81 drought. Portions of the marsh were dry during other intermittent periods throughout the course of the study.

By nature of continued inflows from the north tributary, the Armstrong Slough Marsh was continually inundated. Water levels were controlled by flashboard and culvert riser structures at the outfall location. Water stages in the marsh were predominantly in the 49-50 foot msl range which maintained depths in the marsh of up to three feet in places. Storage in the marsh at stage 49.0 feet msl is estimated to be approximately 17,270m^3 (14 acre-feet) and at stage 50.0' msl, 59,214m^3 (48 acre-feet). At this higher stage mean depth of water in the marsh is estimated to be approximately 0.46 m (1.6 feet). Mean depth in the Ash Slough marsh rarely, if ever, exceeded 0.15m (0.5 feet). For purposes of comparing the physical characteristics of the Ash and Armstrong Slough marshes, constant surface areas (8.1 ha for Ash Slough and 12.1 ha for Armstrong Slough) and average depths (.14m for Ash Slough and .48m for Armstrong Slough) were assumed for each.

Given surface areas and mean depths described above, the Armstrong Slough wetland is roughly 1.5 times larger in surface area than is the Ash Slough wetland and has approximately 4.8 times more storage volume. Monthly flow volumes into each marsh for the study period of record are listed in Tables VI-12a-12c.

Assuming constant storage volume for the appropriate marsh, the average monthly detention time in days was calculated. For Armstrong Slough these ranged from 0.2 to 19.4 days and for Ash Slough, 2.0 to 387 days. Total inflows at Ash Slough for each year of the study were 7.1, 0.6, and 2.4 percent of those measured at Armstrong Slough. The major physical differences between these two marshes were that the Armstrong wetland, while only half again as large in surface area and 4.75 times as large in storage volume, received annually from 14 to 166 times more water than did Ash Slough, and as such, detention times were significantly less and the ratio of marsh substrate surface area per unit volume of water to be treated was far less.

There were five months when no measurable discharge occurred at Armstrong Slough. Likewise there were 20 months of the study where similar conditions occurred at Ash Slough. Maximum monthly inflow for the five months of no discharge at Armstrong Slough was 160,000m^3 (less than 130 acre-feet). There were three months in which inflows of less than this amount occurred yet measurable discharge was noted. In each of these latter cases it could be argued that measured discharge was due to residual runoff from water in storage or groundwater contributions from saturated soils as preceding months were usually characterized by rainfall and larger inflows. At Ash Slough measured inflows as great as 13,200m^3 (10.7 acre-feet) did not result in measurable discharge during the drought year. At the other extreme there was discharge during three events when monthly inflows were less than 10,000m^3 (8.1 acre-feet). As at Armstrong Slough inflows during antecedent months had been relatively high.

Based on these observations in the absence of antecedent runoff producing events, it appears that a minimal threshold volume of monthly inflow is necessary to produce outflow. Volumes of less than these amounts are totally lost through evapotranspiration and seepage to groundwater.

Mean annual time series and flow weighted concentrations of N and P species at Armstrong and Ash Sloughs are depicted in Figures VI-21 through VI-24.

Mean time series concentrations of particulate N and dissolved and particulate P are lower in inflows at Armstrong Slough than at Ash Slough. Dissolved inorganic N concentrations are more nearly identical, generally being low in inflow to both wetlands. At Armstrong Slough mean annual time series concentrations are reduced at the outfall for all parameters except for phosphorus during the last year of the study. At the Ash Slough outfall mean annual time series concentrations of phosphorus were reduced during the first year; however, nitrogen concentrations were enhanced at the marsh outfall (both inorganic and total) as well as ortho and total P concentrations during the last two years.

Annual flow weighted inorganic N concentrations in inflows to the Ash Slough marsh are nearly the same as those flowing into Armstrong Slough. Flow weighted total N concentrations of flow entering the Ash Slough marsh are slightly greater than those entering Armstrong Slough. With the exception of the second year of the study when flow weighted ortho and total P concentrations into the Armstrong Slough marsh were more similar to (but still less than) those at Ash Slough, concentrations of these species entering the marsh at Ash Slough were consistently an order of magnitude greater than those entering the Armstrong Slough marsh. Dissolved inorganic N concentrations were roughly 2 to 4 percent of total N concentrations at Ash Slough and 2 to 8 percent of those at Armstrong. Ortho P, however, constituted 73 to almost 100 percent of the total P concentrations at Ash, while usually only 23 to 45 percent at Armstrong Slough.

Annual flow weighted concentrations of N and P species at the Armstrong Slough outfall were less than those at the major contributing tributary during all but the last year when total P concentrations at the outfall were greater than those measured at either of the two inflow tributaries. Annual flow weighted concentrations of total and ortho P at the Ash Slough outfall were less than flow weighted concentrations from the major contributing watershed. Flow weighted inorganic and total N concentrations at the marsh outfall were higher than inflow concentrations from the contributing watershed during the final year of the study.

In summary, the Armstrong Slough marsh consistently reduced concentrations (both time series and flow weighted) of dissolved inorganic N. By contrast, concentrations of this parameter were consistently greater at the outfall of the Ash Slough marsh than those noted at the major inflow tributary. Total N concentrations (both time series and flow weighted) at Armstrong Slough were reduced only slightly below those noted coming from the contributing watersheds. At Ash Slough total N concentrations, both time series and flow weighted, were consistently increased.

Dissolved ortho P concentrations at Armstrong Slough were reduced as at Ash Slough, with the exception of the drought year when time series

TABLE VI-12a. MONTHLY TURNOVER RATES AND MEAN RESIDENCE TIMES FOR FLOW VOLUMES THROUGH THE ARMSTRONG AND ASH SLOUGH WETLANDS 1979-80

Month	Armstrong Slough Mean Depth 1.6 Feet			Ash Slough Mean Depth 0.5 Feet		
	Flow In (m^3)	Turnover Per Month	Detention Time (Days)	Flow In (m^3)	Turnover Per Month	Detention Time (Days)
October	4,315,430	72.9	0.4	49,363	4.00	7.8
November	202,925	3.4	8.8	931	0.08	375.0
December	188,579	3.2	9.7	3,955	0.32	96.9
January	146,949	2.5	12.4	4,460	0.36	86.1
February	447,437	7.6	3.7	36,939	2.99	9.4
March	394,325	6.7	4.6	15,645	1.27	24.4
April	213,884	3.6	8.3	99,707	8.08	3.7
May	261,725	4.4	7.0	1,397	0.11	281.8
June	147,248	2.5	12.0	5,817	0.47	63.8
July	206,480	3.5	8.9	92,856	7.53	4.1
August	862,535	14.6	2.1	52,332	4.24	7.3
September	304,331	5.1	5.9	182,979	14.83	2.0
TOTAL	7,691,953	129.9	2.8*	546,382	44.29	8.2*

*Mean Annual

TABLE VI-12b. MONTHLY TURNOVER RATES AND MEAN RESIDENCE TIMES FOR FLOW VOLUMES THROUGH THE ARMSTRONG AND ASH SLOUGH WETLANDS 1980-81

Month	Armstrong Slough Mean Depth 1.6 Feet			Ash Slough Mean Depth 0.5 Feet		
	Flow In (m^3)	Turnover Per Month	Detention Time (Days)	Flow In (m^3)	Turnover Per Month	Detention Time (Days)
October	134,186	2.3	13.4	931	0.08	387.5
November	179,403	3.0	10.0	7,445	0.60	50.0
December	149,255	2.5	12.4	1,626	0.13	238.5
January	126,723	2.1	14.8	0	0	
February	302,755	5.1	5.5	5,352	0.43	65.1
March	174,819	3.0	10.3	1,397	0.11	281.8
April	152,928	2.6	11.5	0	0	
May	160,578	2.7	11.5	2,794	0.23	134.8
June	206,160	3.5	8.6	4,420	0.36	83.3
July	113,697	1.9	16.3	9,773	0.79	39.2
August	1,707,570	28.8	1.1	13,262	1.08	28.7
September	6,779,565	114.5	0.3	11,556	0.94	31.9
TOTAL	10,175,053	171.8	2.1*	58,557	4.75*	76.8*

*Mean Annual

TABLE VI-12c. MONTHLY TURNOVER RATES AND MEAN RESIDENCE TIMES FOR FLOW VOLUMES THROUGH THE ARMSTRONG AND ASH SLOUGH WETLANDS 1981-82

Month	Armstrong Slough Mean Depth 1.6 Feet			Ash Slough Mean Depth 0.5 Feet		
	Flow In (m^3)	Turnover Per Month	Detention Time (Days)	Flow In (m^3)	Turnover Per Month	Detention Time (Days)
October	464,801	7.8	4.0	1,160	0.09	344.4
November	432,147	7.3	4.1	1,748	0.14	214.3
December	94,693	1.6	19.4	0	0	
January	160,792	2.7	11.5	2,411	0.20	155.0
February	354,945	6.0	4.7	5,123	0.42	66.7
March	635,247	10.7	2.9	45,819	3.71	8.4
April	2,165,107	36.6	0.8	156,774	12.71	2.4
May	1,172,701	19.8	1.6	8,705	0.71	43.7
June	6,948,955	117.4	0.3	182,118	14.76	2.0
July	3,251,541	54.9	0.6	102,232	8.29	3.7
August	4,062,019	68.6	0.5	61,047	4.95	6.3
September	8,303,083	140.2	0.2	98,098	7.95	3.8
TOTAL	28,046,032	473.6	0.8*	665,153	53.92	6.8*

*Mean Annual

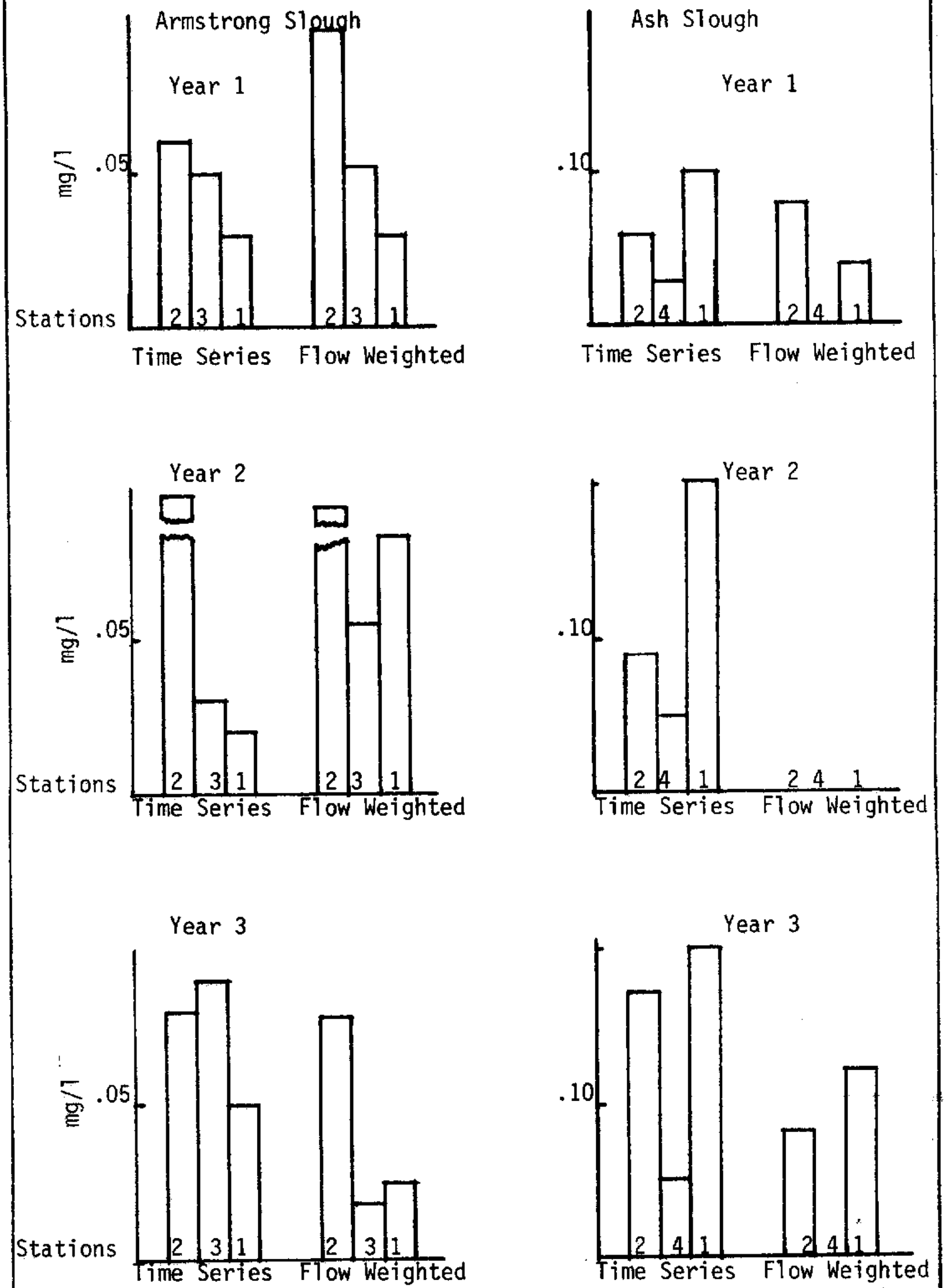


Figure VI-21. Mean Annual Time Series and Flow Weighted Concentrations for Dissolved Inorganic Nitrogen at Inflow and Outfall Stations in Upland Demonstration Project Detention Wetlands.

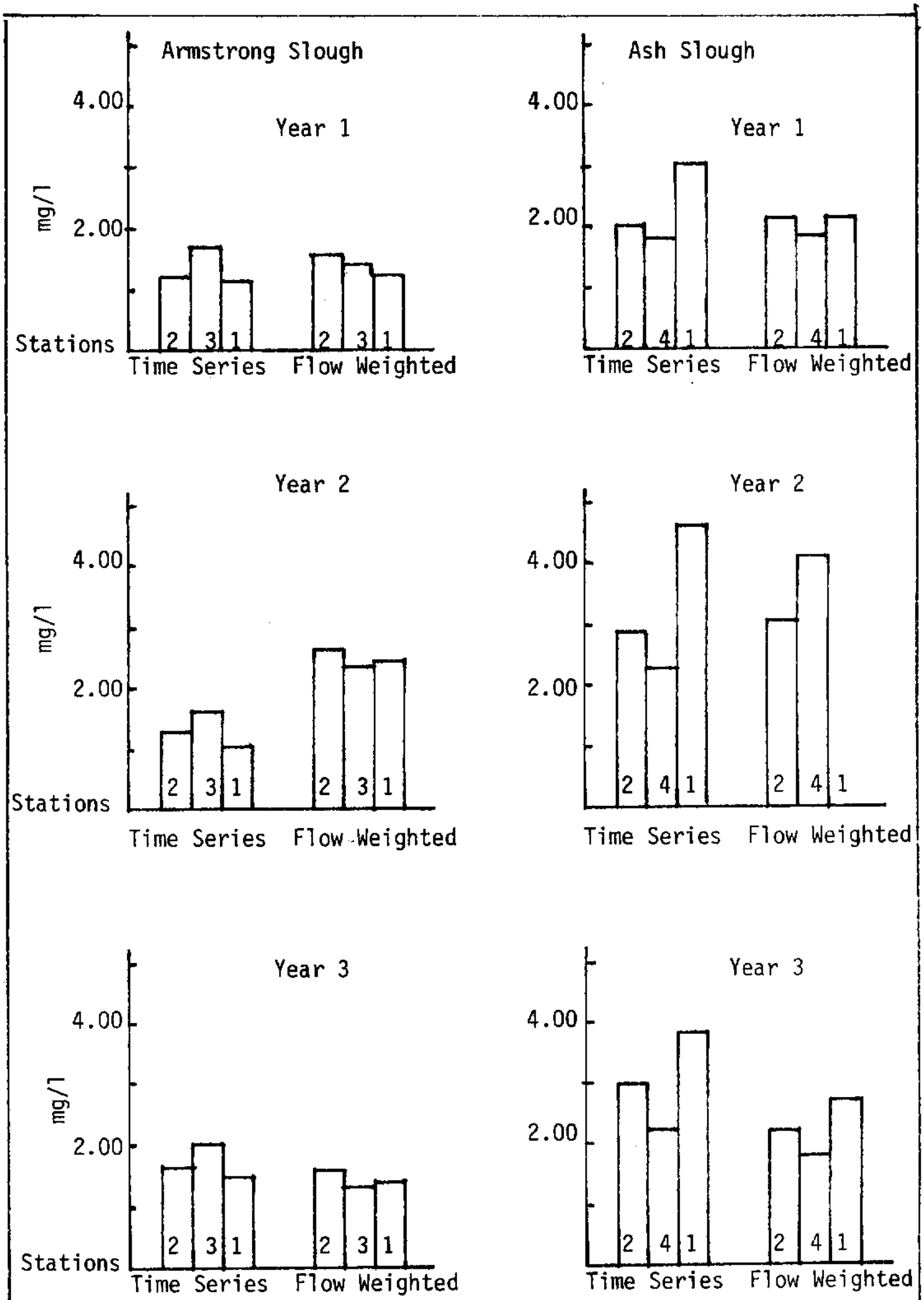


Figure VI-22. Mean Annual Time Series and Flow Weighted Concentrations for Total Nitrogen at Inflow and Outfall Stations in Upland Demonstration Project Detention Wetlands.

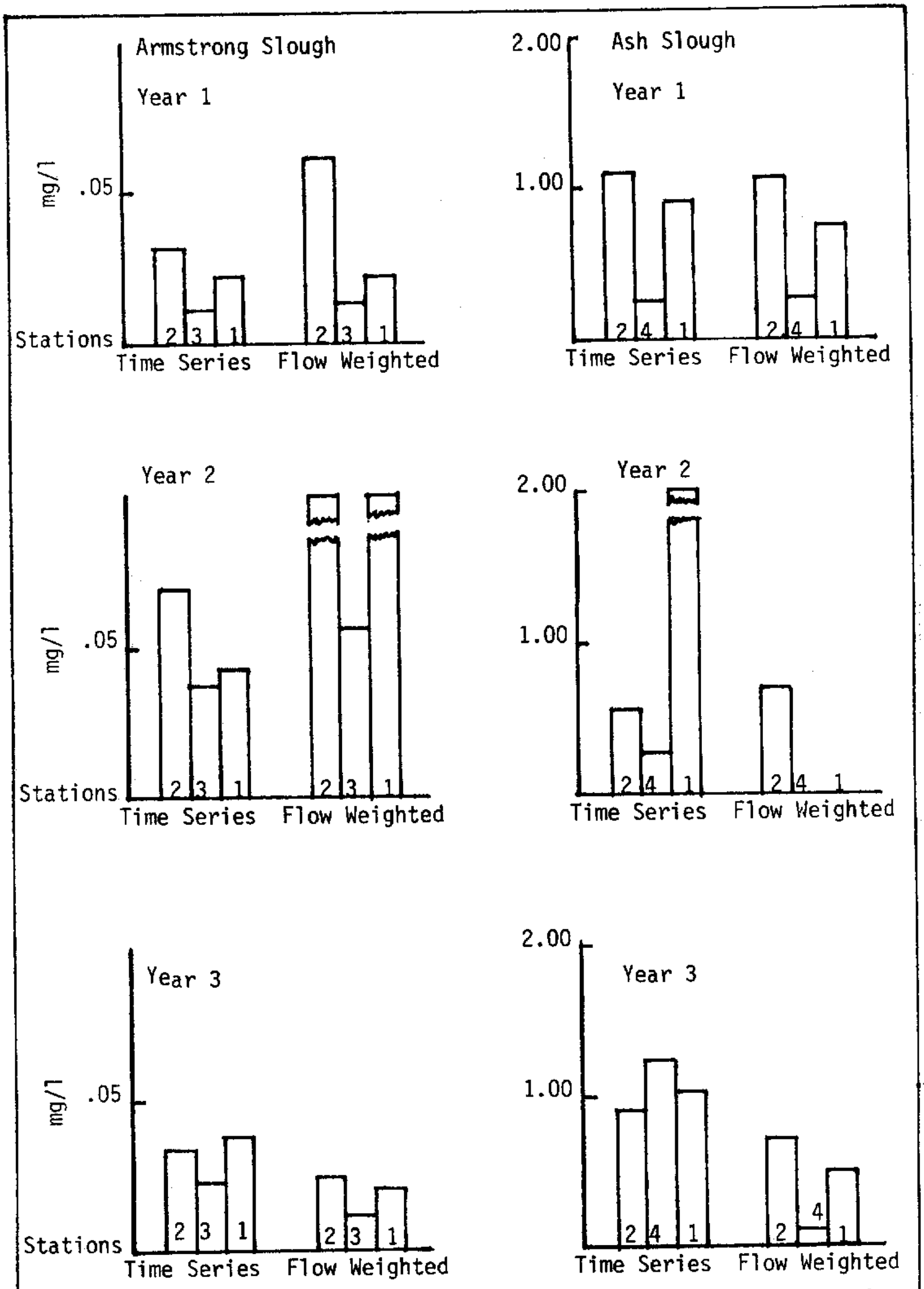


Figure VI-23. Mean Annual Time Series and Flow Weighted Concentrations for Ortho Phosphorus at Inflow and Outfall Stations in Upland Demonstration Project Detention Wetlands.

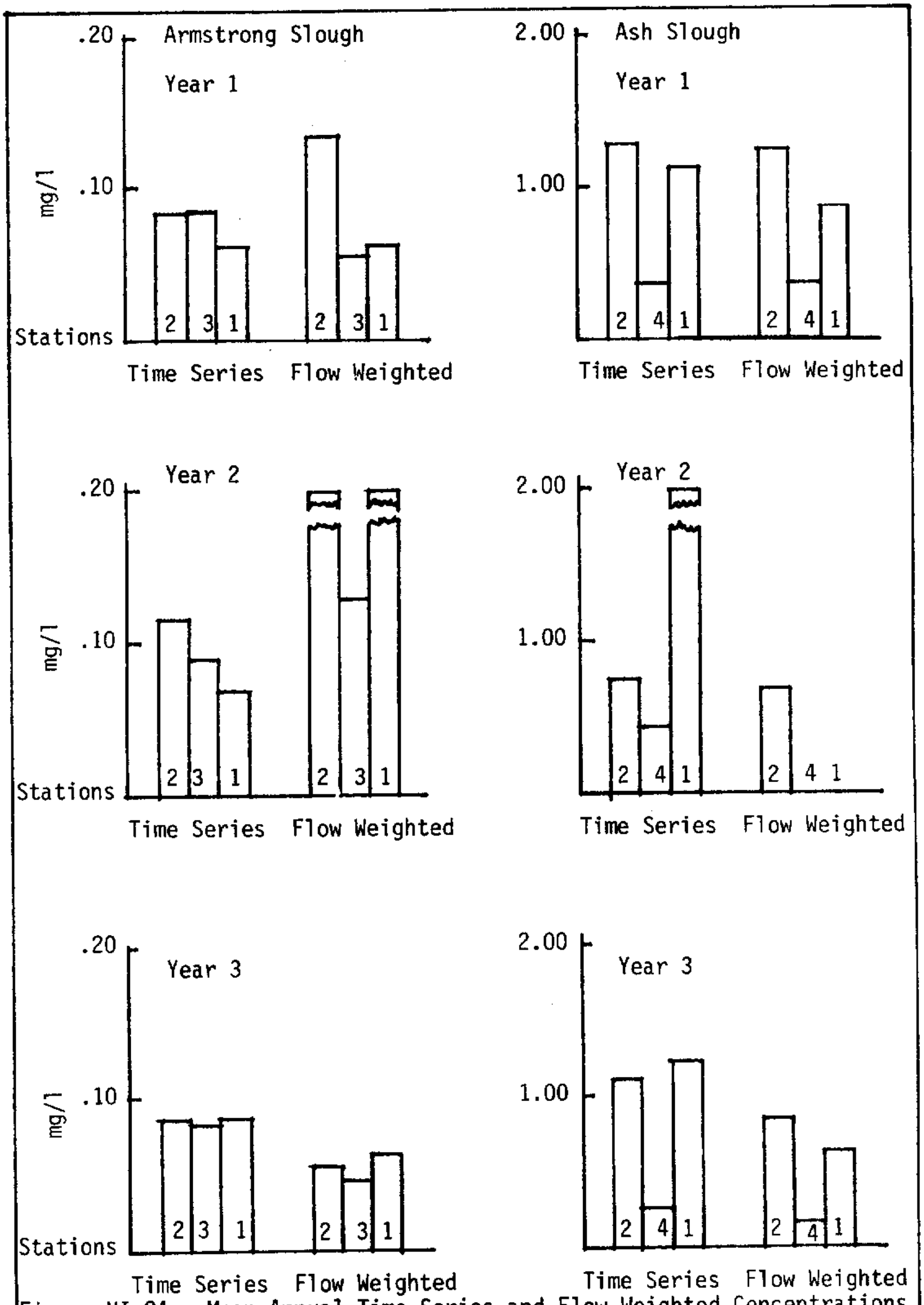


Figure VI-24. Mean Annual Time Series and Flow Weighted Concentrations for Total Phosphorus at Inflow and Outfall Stations in Upland Demonstration Project Detention Wetlands.

concentrations at the marsh outfall were significantly increased. There was no surface discharge from the wetland at this time, therefore, those enhanced concentrations had no impact on flow weighted concentrations and downstream water quality.

Reductions of time series and flow weighted total P concentrations at Armstrong Slough occurred during all but the final year of study when they were essentially unchanged or even slightly enhanced. Both time series and flow weighted concentrations of total P were generally reduced at Ash Slough. The exceptions noted for the ortho P concentrations at the marsh outfall during the drought year holds true for total P. In addition time series concentrations of total P at the outfall were slightly greater during the final year of the study.

Evaluating these results in an alternate way, during the first year both marshes reduced ortho and total P concentrations as well as inorganic N but were not effective with particulate organic N since little, if any real reduction in total N concentrations was apparent. These same trends held true during the second year of the drought, although, ortho and total P concentrations at the Ash Slough outfall were exceptionally high. Since no measurable discharge occurred, there was no resultant water quality input downstream. Water quality during the final year of the study was characterized by continued reduction of dissolved inorganic N concentrations at Armstrong Slough but increases in the Ash Slough marsh; little if any total N reduction at Armstrong while increases occurred at Ash; slight reduction in ortho P concentrations at both Armstrong and Ash; and little, if any, total P concentration reduction by either wetland.

In the final analysis, the ultimate test of a wetland's utility as a detention/retention best management practice is its ability to reduce nutrient loads. It is in this facet of the comparison of these two wetlands that the most obvious differences and yet some of the most similar characteristics become apparent.

The physical similarities and differences between the two wetlands have already been described. During the three years of study the Armstrong Slough wetland was subjected to 14.1, 173.8, and 42.2 times more flow volume annually than that occurring at the Ash Slough wetland.

Assuming constant wetland surface area at each location, each hectare of wetland at Armstrong Slough was subjected to flow volumes ranging from 635,700 m^3 to over 2,317,800 m^3 per year. By comparison, each hectare of Ash Slough wetland was subjected to flow volumes of 7,230 m^3 to 82,120 m^3 annually. Over the course of the three years a given hectare of Armstrong Slough marsh was annually subjected to up to 300 times the volume for treatment than a given hectare of Ash Slough marsh.

In year two, minimal inflow into the Ash Slough marsh from surface runoff occurred. During this period, there was no measurable discharge from the marsh. Under these circumstances, the uptake efficiency of this wetland was constantly 100 percent. It is unknown how much more load the marsh could have absorbed had there been more inflow or what the discharge load would have been had any occurred. Given these circumstances, it was decided that for the purposes of this discussion inclusion of treatment efficiencies, or comparison of load uptake at Ash Slough with that at Armstrong Slough for this year, would not be appropriate as Ash Slough data of marsh uptake might bias the general conclusions about the long term efficiency of these systems. For this reason, those data collected during the second year of study at Ash Slough will be eliminated from the general comparison of these two wetlands.

With the exception of dissolved inorganic N, mean annual nutrient concentrations in surface flow into the Armstrong Slough marsh were less than those of flow into the Ash Slough wetland. Mean total N concentrations of surface flow into Armstrong Slough were roughly half those noted going into Ash, while ortho P concentrations of surface flow into Ash ranged from 5 to 34 times greater than those into Armstrong, and total P concentrations ranged from 3 to 15 times more. These, of course, impacted actual loads going into the marshes. As a result, inorganic N loads into Armstrong Slough marsh per hectare surface area were 3.5 to 7.5 times more than those at Ash Slough, while total N loads were 5 to 14 times more per unit area. By contrast, ortho P and total P loads per unit surface area were usually greater at Ash Slough by factors of 1.2 to 2.4 times. Only during year three when there was a large volume of flow into Armstrong Slough was the wetland surface, P loaded at a greater rate (1.5 times) than those that occurred at Ash Slough.

Net nutrient load uptake or export was plotted against mass loads into the marsh on an annual per unit surface area basis. These data are depicted in Figures VI-25 and VI-26. These plots graphically illustrate the relative differences in loading rates and areal retention rates that occurred at the two marshes for the three years. In addition, efficiency isopleths as percent uptake are delineated and thus the relative efficiency of each wetland can be compared over the years for each parameter.

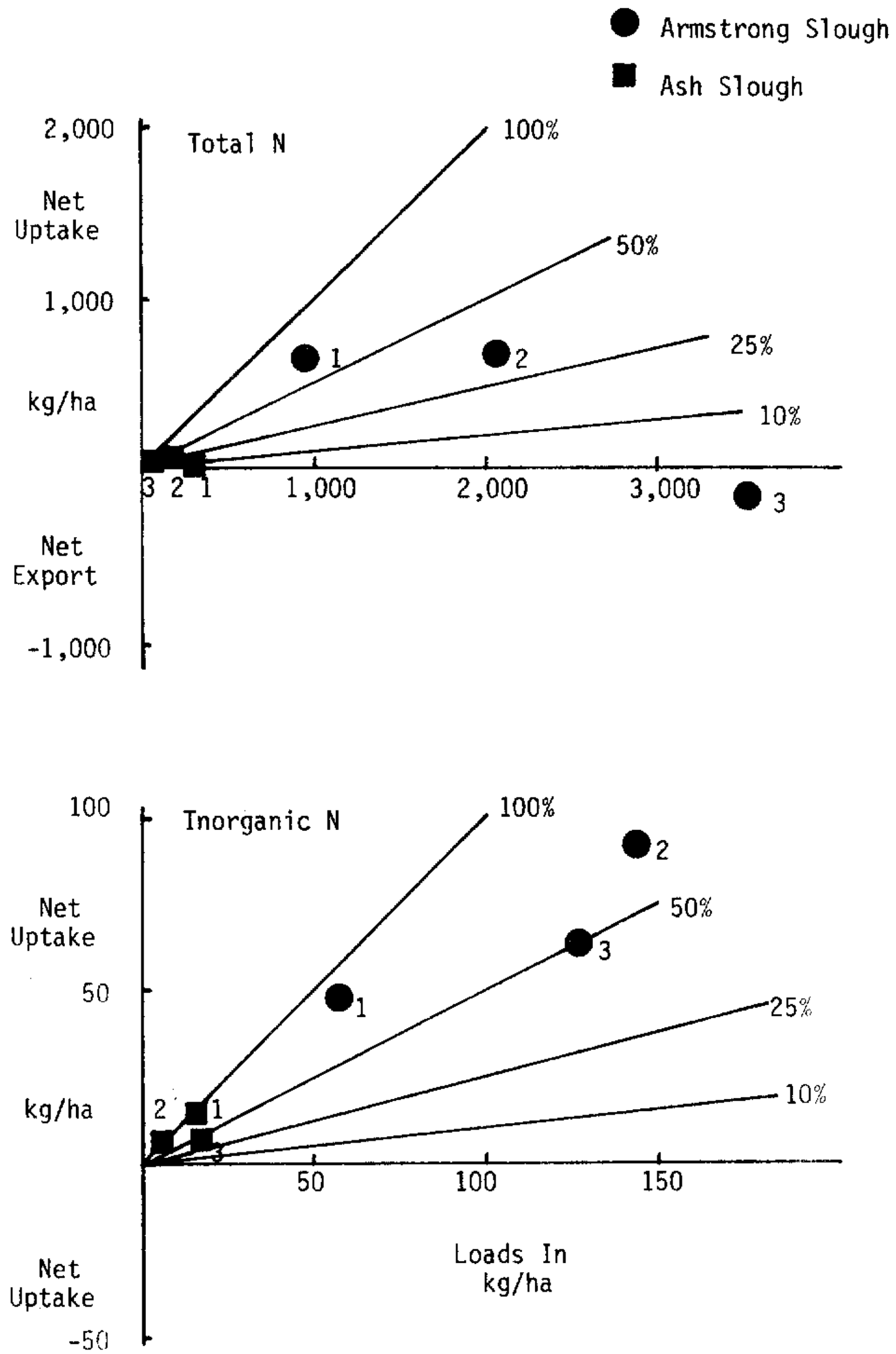


Figure VI-25. Annual uptake/export rates versus loading rates of total and inorganic nitrogen at the Armstrong and Ash Slough wetlands.

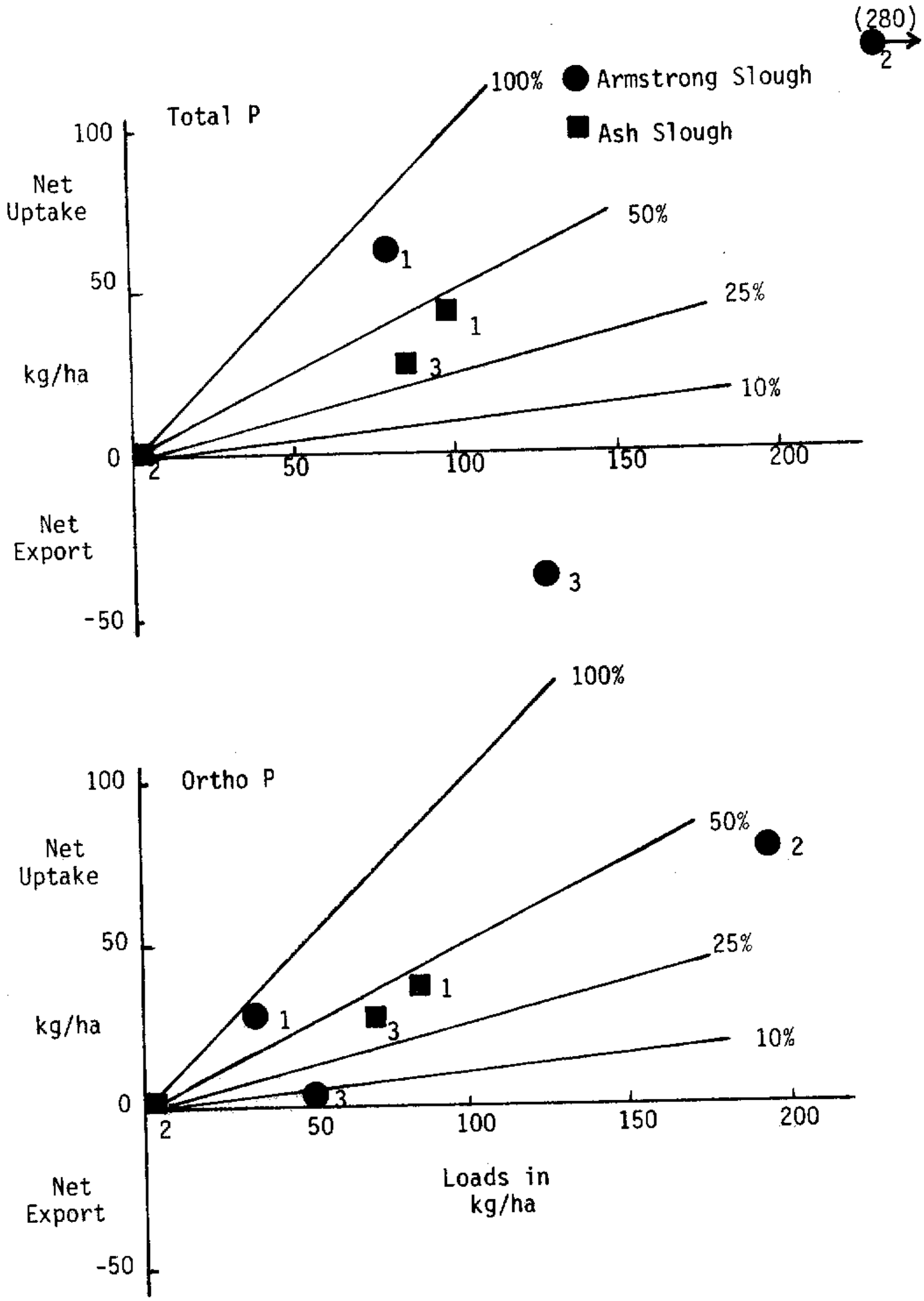


Figure VI-26. Annual uptake/export rates versus loading rates of total and ortho phosphorus at the Armstrong and Ash Slough wetlands.

The difference in loading rate and subsequent retention rates for total and inorganic N are most obvious. Uptake efficiency for dissolved inorganic N is consistently the best at both sites over all three years (50 percent or better in all but one case). Efficiency of total N uptake is relatively low in both wetlands (less than 50 percent) in almost all cases and during the last year net export was calculated to have occurred at the Armstrong Slough marsh. This was predominantly in the form of particulate N.

With the exception of the second year of the study, areal loading rates of ortho and total P are similar at the two wetlands. Uptake efficiency of the ortho and total P components appears to be fairly consistent at Ash Slough, ranging from 25 to 50 percent of the total loading. This same percentage of uptake held for Armstrong Slough during the second year of the study when that wetland experienced an inordinately high loading rate.

Uptake efficiencies for dissolved and total P at Armstrong Slough were the highest of any calculated during the first year and the lowest of any calculated during the third year when the wetland was actually a net exporter of total P.

A trend that appears to be consistent at both sites throughout the study is one of decreasing uptake efficiency of both N and P through each of the three years. Whether or not this is a long term characteristic or merely an artifact of the hydrological regimes that prevailed during those years is not certain. A newly created wetland might be expected to be more efficient at nutrient removal than an older one due to available adsorption capacity of the soils and area available for growth of aquatic vegetation. Older wetlands would have supposedly exhausted much of this capacity and without some ongoing harvest mechanism should theoretically reach a steady state condition (at least in relationship with P). A gradual loss of uptake capacity is possibly being observed during this study; but, without additional data collected under conditions of more similar rainfall and runoff, definite conclusions are premature.

In general, it can be concluded that the wetlands function best in uptake of dissolved inorganic N. They function less well, but are still relatively effective in uptake of ortho and total P. They function least well for uptake of total N. It should also be noted that larger loading rates generally resulted in larger uptake rates. Lowest uptake efficiencies occurred during the year of highest flows and theoretical lowest detention times. Physical uptake of nutrients in the marshes was as high as 688 kg/ha for total N at Armstrong Slough and 53.2 kg/ha at Ash, while up to 121.3 kg/ha for total P at Armstrong and 43.2 kg/ha at Ash. During the final year of study, Armstrong Slough was determined to be a net exporter of both total N and total P.

DISCUSSION

Mechanisms governing nitrogen and phosphorus flux in wetlands and sediments have been extensively discussed in reviews by Keeney (1972), Kadlec and Tilton (1979), Reddy et al (1978), and Nichols (1983). Nutrient removal is generally attributed to sorption, precipitation, mineralization, or biochemical processes associated with microbial activity or vegetative uptake.

A variety of biological and chemical processes function to convert nitrogen to or from organic and dissolved inorganic forms (NH_4^+, NO_3^-, NO_2^-, N_2). While vegetative uptake (usually of NH_4^+ or NO_3^-) is one pathway for N removal, nitrification-denitrification processes probably serve as the major mechanism. Wetlands are particularly suited to N removal via this mechanism by nature of charac-teristically large surface area to volume ratios and abundance of rooted macrophytic vegetation, all of which provide necessary substrate for the bacterial species required to catalyze these processes. Nitrification (the conversion of NH_4+ to NO_3^-) requires aerobic conditions that occur on the surface layer of the soil or in the water column. Lack of oxygen or availability of NH_4^+ can limit the rate of nitrification reactions. Denitrification (a bacterial conversion of NO_3^- to NO_2^- and subsequent conversion to gaseous N_2) occurs under anaerobic conditions. As NO_3^- produced by nitrification reactions diffuses into the layers immediately beneath the soil/water interface, the latter reaction takes place. The resulting nitrogen gas is subsequently released to the water column and/or atmosphere. Denitrification has been found by Graetz and Cambell (1982) to be actively occurring in the Ash and Armstrong Slough detention/retention wetlands.

Phosphorus removal is attributed primarily to sorption/precipitation phenomena although uptake or conversion via biochemical pathways is also important. Sorption appears to have both chemical and physical phases. Soluble inorganic P is readily adsorbed onto aluminum, iron, or calcium in a chemical reaction that binds phosphate ions to the mineral complex. This occurs at equilibrium concentrations of phosphate P of up to about 1.0 mg/l. Above 1.0 mg/l physical adsorption is the predominant mechanism. Physically adsorbed P is not held as tightly as that chemically adsorbed and can easily be described in more dilaute solutions (Ryder, 1977 cited in Nichols, 1983).

The ability of soils to adsorb and hold P has been described by empirically derived mathematical expressions such as the Langmuir and Freundlich isotherms. P adsorption has also been described in terms of an equilibrium P concentration (EPC) where P is adsorbed and desorbed at equal rates in an equilibrium that exists between P adsorbed in the soil and P dissolved in the surrounding water column. EPC values indicate the capacity of soils to adsorb or desorb when that soil is in contact with liquid of a given P concentration. Increasing EPC values indicate decreasing sorption capacity of the soil (Reddy, 1978).

The ability of natural wetlands to serve as polishing systems for primary and secondarily treated wastewater has been investigated and reported by Kadlec (1975), Kadlec and Tilton (1977, 1978, 1979), Kadlec et al. (1979), Kadlec and Hammer (1981), Eisel (1976), Spangler et al. (1976), Boyt et al. (1977), Ewel and Odum (1978), Fetter et al. (1978), Mudrock and Capobianco (1979), Dolan et al. (1981), and Dierberg and Brezonik (1983) to name a few. Variability of results of nutrient removal studies between sites is due to numerous factors including nutrient loading rate, water depth, season, soil type, vegetation type and density, wetland type, and hydraulic retention time.

Uptake efficiencies reported in the literature are often difficult to compare on a wetland to wetland basis as documented studies often report only reduction in concentrations. Few studies have been done where actual mass load reductions have been calculated and results reported on a unit uptake per unit surface area per unit time basis.

Typical nutrient uptake efficiencies of wetlands based on concentrations are reported by Kadlec and Tilton (1979) and by Davis (1981). Tables VI-13 and VI-14 contain a summary of some reported total N and total P reduction efficiencies by wetlands. These data are augmented by results from this and other studies conducted in the south central Florida area, notably those in the Chandler Slough marsh (Federico et al., 1978) and Boney Marsh (Davis, 1981).

Concentrations of total N in inflows and discharges from Armstrong and Ash Slough are comparable to concentrations of total N noted in the inflows and discharges at the other south central Florida study sites. This is not surprising as both Chandler Slough and Boney Marsh are, like the subject study sites, located in the Kissimmee River drainage basin and land uses of the contributing watersheds are fairly similar. Loading and per unit area uptake, however, reveals dissimilarities. Hydrological regimes are of primary importance in determining the amount of nutrient load delivered to these wetlands. Armstrong Slough annual total N loadings per unit surface area are an order of magnitude greater than those rates at Ash and Chandler Sloughs and greater still than those reported for Boney Marsh. Annual per unit area uptake of nitrogen by the wetland was also initially far greater than that noted for the other sites. Percent uptake/efficiency decreased during each year and was comparable during the last two years to uptake/export rates noted at Chandler Slough and Boney Marsh.

The Ash Slough wetland was loaded more comparably to Chandler Slough and the flow-through Boney Marsh wetland. Uptake efficiency decreased over the course of the study but fell within the ranges noted for the other Kissimmee basin wetlands. In summary, uptake efficiency of total N at Ash and Armstrong Sloughs, while initially high, appears to be of the same general magnitude of those noted in other Kissimmee basin wetlands. As total N concentrations are comparable in inflows, hydrological regime and wetland surface area are primary factors that determine areal loading rates. In those cases where little or no flow leaves the wetland, uptake efficiencies become exceedingly good.

Total P concentrations in inflow at Armstrong Slough are either roughly equivalent to or slightly higher than those noted at Boney Marsh. Concentrations of inflow at Ash Slough are of the same order of magnitude but somewhat greater than those noted in inflow at Chandler Slough. Influent concentrations at the Kissimmee basin wetlands are substantially less than many others reported in the literature; however, most other studies evaluating P uptake by wetlands are associated with the evaluation of wetland ability to polish sewage effluent. This was not the case at any of the Kissimmee River basin wetlands.

The Ash and Chandler Slough watersheds are subjected to a higher intensity land use in terms of cultural phosphorus loads than are the Armstrong Slough and Boney Marsh wetlands. This accounts for the differences in total P concentrations in runoff entering these wetlands. Many of the referenced studies conducted outside of Florida report high reduction efficiencies of total P concentrations by wetlands. Others such as those by Fetter, et al. (1978) and Peverly (1982) demonstrate less effective reduction rates that are more in character with those noted in the south central Florida wetland studies.

Phosphorus uptake efficiency (loads retained per unit marsh surface area) appears to be highly

TABLE VI-13. REDUCTION EFFICIENCIES FOR TOTAL N IN WETLANDS AS REPORTED IN THE LITERATURE
(mg/L concentrations)

Location	Inflow	Outflow	% Reduction	Source
Central Florida	15.3	1.6	89.5	Boyt et al, 1977
Hungary	19.97	0.81	96	Toth, 1972
Brookhaven, New York	30.00	5.00	83	Small, 1978
Wisconsin	4.72	2.84	40	Klopatec, 1975
+Chandler Slough 1975	1.34	1.39	-3.7	Federico et al, 1978
+Chandler Slough 1976	1.42	1.38	-2.8	Federico et al, 1978
+Ash Slough 1980	2.06	2.14	-3.9	This Study
+Ash Slough 1981	3.15	NA	NA	This Study
+Ash Slough 1982	2.22	2.75	-23.9	This Study
+Armstrong Slough 1980	1.52	1.28	15.8	This Study
+Armstrong Slough 1981	2.59	2.46	5.	This Study
+Armstrong Slough 1982	1.53	1.47	3.9	This Study
+Boney Marsh 1976	1.36	1.32	2.9	Davis, 1981
+Boney Marsh 1977	1.46	1.42	2.7	Davis, 1981
+Boney Marsh 1978	1.47	1.47	0	Davis, 1981

+Flow Weighted Concentration
* Molybdate Reactive P

Mass Uptake/Export
kg/ha/yr

Location	Load On Marsh	Uptake/ Export	% Uptake Export	Source
Chandler Slough 1975	37.6	4.2	11.2	Federico, 1978
Chandler Slough 1976	51.9	16.0	30.8	Federico, 1978
Boney Marsh 76-79 (flow through)	6.1	4.3	69	Davis, 1981
Boney Marsh 76-79 (no flow)	2.3	2.1	94	Davis, 1981
Ash Slough 1980	98.8	43.2	43.7	This Study
Ash Slough 1981	1.3	1.3	100.0	This Study
Ash Slough 1982	85.6	29.2	34.1	This Study
Armstrong Slough 1981	282.1	121.3	43.0	This Study
Armstrong Slough 1980	79.2	62.7	79.2	This Study
Armstrong Slough 1981	282.1	121.3	43.0	This Study
Armstrong Slough 1982	128.9	-32.3	-25.1	This Study
New York 77-78	.42	.68	-61.9	Peverly, 1982
New York 78-79	1.28	.47	-63.3	Peverly, 1982

TABLE VI-14. REDUCTION EFFICIENCIES FOR TOTAL P IN WETLANDS AS REPORTED IN THE LITERATURE

(mg/L concentrations)

Location	Inflow	Outflow	% Reduction	Source
Hungary	4.5	0.08	98	Toth, 1972
Canadian, NW Territory	11.0	0.26	97	Price, 1975
New York	.2-1.7*	.1-.3*		Peverly, 1982
Wisconsin	24.0	12.0		Spangler et al, 1976
Central Florida	6.4	1.0	98	Boyt et al, 1977
Michigan	3.48	0.11	97	Kadlec & Tilton, 1978
Michigan	0.41	0.05	95	Kadlec & Tilton, 1978
+Chandler Slough 1976	0.349	0.226	35	Federico et al, 1978
+Chandler Slough 1975	0.276	0.232	16	Federico et al, 1978
Boney Marsh 1976	.035	.022	37	Davis, 1981
Boney Marsh 1977	.045	.021	53	Davis, 1981
Boney Marsh 1978	.047	.017	54	Davis, 1981
+Ash Slough 1980	1.19	0.87	26.9	This Study
+Ash Slough 1981	0.68		NA	This Study
+Ash Slough 1982	0.82	0.64	-22.0	This Study
+Armstrong Slough 1980	0.125	.062	50.4	This Study
+Armstrong Slough 1981	0.347	.271	21.9	This Study
+Armstrong Slough 1982	.051	.063	-82.4	This Study
Wisconsin	2.61	1.78	32	Fetter et al, 1978

+Flow Weighted Concentration

Mass Uptake/Export
kg/ha/yr

Location	Load On Marsh	Uptake/Export	% Uptake Export	Source
Chandler Slough 1975	197	-1.6	-0.8	Federico
Chandler Slough 1976	203.9	-9.6	-4.7	Federico
Ash Slough 1980	190.4	53.2	27.9	This Study
Ash Slough 1981	16.7	16.7	100.	This Study
Ash Slough 1982	250.2	9.1	3.6	This Study
Armstrong Slough 1980	973	634	65.2	This Study
Armstrong Slough 1981	2151	688	32.	This Study
Armstrong Slough 1982	3578	-187	-5.2	This Study
Boney Marsh 76-79 (flow through)	167.9	39.9	24	Davis
Boney Marsh 76-79 (no flow)	38.6	31.3	81	Davis

dependent on flow regimes. Predominantly palustrine wetlands such as the Boney Marsh no-flow system and Ash Slough can theoretically experience 100 percent uptake during years when no discharge occurs as was the case at Ash Slough during the 1980-81 season. Efficiencies decrease as discharge volumes approach inflow volumes, and in cases such as at Armstrong Slough during 1982 when the water budget was such that measured surface outflows exceeded measured surface inflows, there was an apparent net export. This was also enhanced by the increased mean flow weighted concentration of total P at the outfall during this period.

A second generalization that can be drawn from a comparison of these wetland data is that it appears to be a general rule of thumb that higher absolute per unit area loading of P on the marsh surface results in higher absolute per unit area uptake by the marsh (Figure VI-27). This phenomenon is probably a result of the physical-chemical equilibria responses described by Reddy et al. (1978). Greater concentrations in the water column force the equilibrium towards adsorptive processes though the retention efficiency of the marshes tend to decrease. The apparent good efficiency of uptake at Armstrong Slough during 1979-80 can be in large part explained by the fact that this was the first year of operation of the newly created wetland. Uptake efficiencies could be expected to be greater during that year due to newly available substrate storage sites and increased incorporation into biomass as predominant marsh vegetation was becoming established. Uptake efficiencies at Armstrong Slough decreased in each year subsequent to that time. Established wetlands in the Kissimmee basin and elsewhere appear to function consistently at efficiencies of less that 50 percent removal of phosphorus loads. In some cases such as at Oak Orchid Creek in New York, the wetland appears to have reached a steady state equilibrium with the naturally occurring phosphorus inputs from agricultural runoff (Peaverly, 1982). In cases where additional P is being forced into the system, such as those used for polishing of wastewater, uptake efficiency appears to decrease over time (Tilton and Kadlec, 1977).

In conclusion, the Ash and Armstrong Slough wetlands appear to function very similarly to the other Kissimmee River basin wetlands in terms of their ability to remove N and P loads. These wetlands appear to be in near steady-state equilibrium with respect to total N. They also seem to function at the same level of efficiency as phosphorus sinks (below 50 percent). There is ample evidence in the literature that wetlands will reach steady-state conditions when adsorptive capacity for P is spent. There is evidence that the efficiency of P uptake by the wetlands of this study (especially Armstrong Slough) is consistently decreasing.

The dissolved inorganic portions of the N and P loads are most readily removed by these wetlands. Particulate organic material loads of N and P seem to be less affected and may even be exported from these systems as a result of internal cycling.

Concentrations of total N and P may be reduced slightly, but the major mechanism of load reduction appears to be loss associated with water volume reduction/storage in the wetland. This passive loss is incorporated into sediments, vegetation, or as may be likely, the loss may be in seepage from the wetland into the shallow groundwater table. Ultimate fate of nutrients lost from these systems in these manners is unknown.

The wetlands, then, can slightly attenuate low to moderate level stormwater discharge of water and nutrients from agricultural watersheds by slowing the travel time to ultimate downstream receiving waters and by losing some of the water volume and nutrient load to evapotranspiration and/or seepage to groundwater.

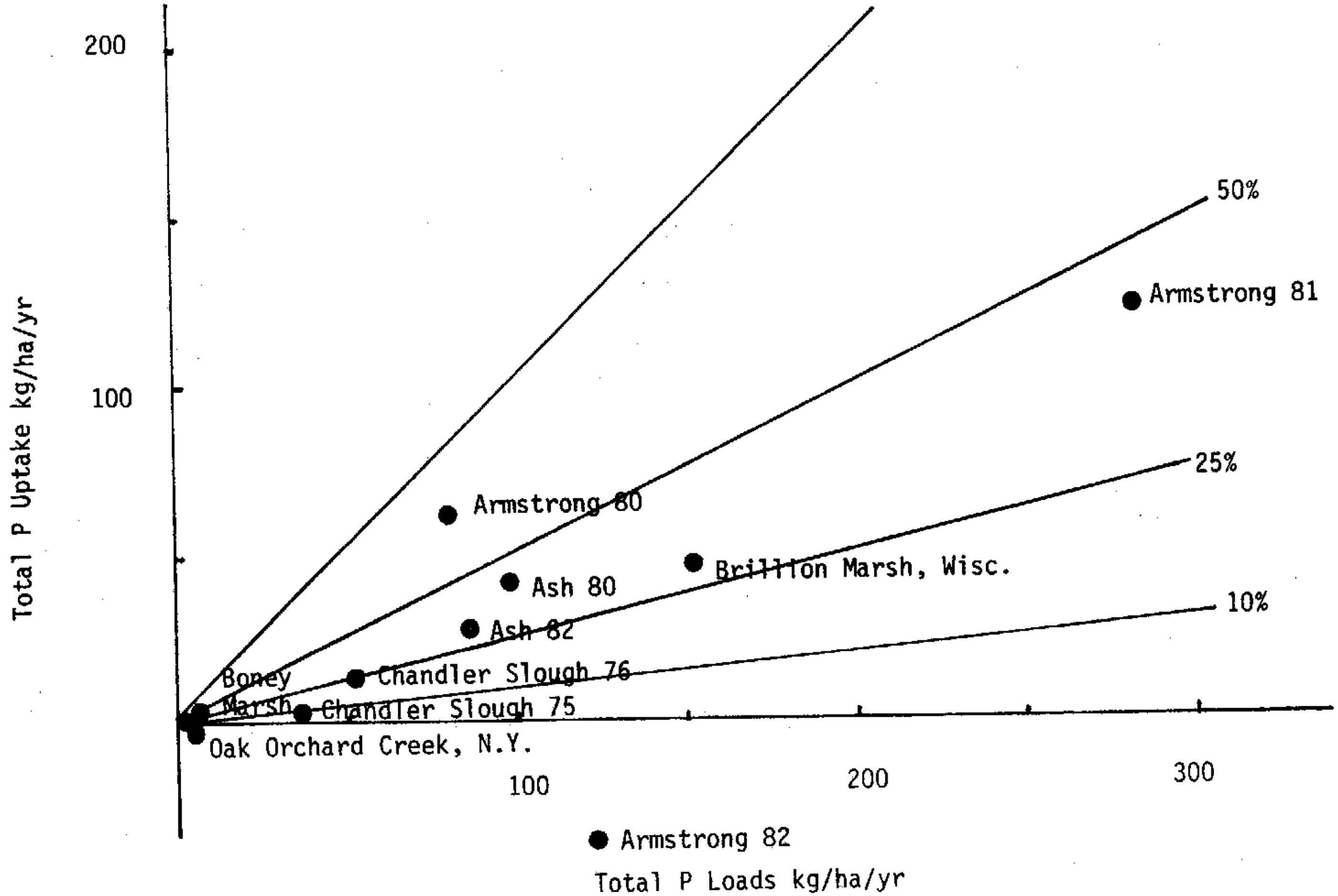


Figure VI-27. Total P uptake verses loading on selected wetlands.

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APPENDIX I

Monthly And Annual Watershed Water And Nutrient Budgets For Upland Demonstration Project Sites

ASH SLOUGH-WEST WATER BUDGET

1979-80

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake +/Discharge-	Percent Net Uptake +/Discharge-
October	10,458	41,107	-30,649	-293.1
November	8,394	0	8,394	100.0
December	35,638	0	35,638	100.0
January	33,574	0	33,574	100.0
February	44,032	25,447	18,585	42.2
March	46,165	7,830	38,335	83.0
April	65,016	91,267	-26,251	-40.4
May	12,594	0	12,594	100.0
June	52,426	0	52,426	100.0
July	151,016	75,119	75,897	50.3
August	134,229	36,458	97,771	72.8
September	136,293	156,598	-20,305	-14.9
ANNUAL TOTALS	729,830	433,826	296,004	40.6

ASH SLOUGH-WEST WATER BUDGET

1980-81

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake + /Discharge-	Percent Net Uptake + /Discharge-
October	8,394	0	8,394	100.0
November	67,080	0	67,080	100.0
December	14,654	0	14,654	100.0
January	0	0	0	-
February	48,229	0	48,229	100.0
March	12,590	0	12,590	100.0
April	0	0	0	-
May	25,181	0	25,181	100.0
June	39,835	0	39,835	100.0
July	88,064	0	88,064	100.0
August	119,506	0	119,506	100.0
September	75,474	2,936	72,538	96.1
ANNUAL TOTALS	499,006	2,936	496,070	99.4

ASH SLOUGH-WEST WATER BUDGET

1981-82

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake+/Discharge-	Percent Net Uptake+/Discharge-
October	10,458	0	10,458	100.0
November	15,755	0	15,755	100.0
December	0	0	0	-
January	20,984	0	20,984	100.0
February	46,165	0	46,165	100.0
March	31,442	42,086	-10,644	-33.9
April	52,288	148,279	-95,991	-183.6
May	60,819	978	59,841	98.4
June	115,309	158,556	-43,247	-37.5
July	94,394	88,087	6,307	6.7
August	106,915	46,490	60,425	56.5
September	132,096	78,055	54,041	40.9
ANNUAL TOTALS	686,624	562,531	124,093	18.1

ASH SLOUGH-WEST NUTRIENT BUDGET

1979-80

INORGANIC N (Kilograms)

Rainfall Loads and Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	7.0	2,318	2,318.0	1	2,317.0	100.0
November	5.6	2,318	2,318.0	0	2,318.0	100.0
December	23.9	0	23.9	0	23.9	100.0
January	22.5	0	22.5	0	22.5	100.0
February	29.5	0	29.5	1	28.5	96.6
March	30.9	0	30.9	1	29.9	96.8
April	43.6	0	43.6	21	22.6	51.8
May	8.4	0	8.4	0	8.4	100.0
June	35.1	0	35.1	0	35.1	100.0
July	101.2	0	101.2	3	98.2	97.0
August	89.9	0	89.9	1	88.9	98.9
September	91.3	0	91.3	6	85.3	93.4
ANNUAL TOTALS	489.0	4,636	5,125.0	34	5,091.0	99.3

ASH SLOUGH-WEST NUTRIENT BUDGET

1980-81

INORGANIC N (Kilograms)

Rainfall Loads and Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer	Total Inorganic N In	Inorganic N Out	Source-Sink +	%
October	5.6	2,318	2,318.0	0	2,318.0	100.0
November	44.7	2,318	2,318.0	0	2,318.0	100.0
December	9.8	0	9.8	0	9.8	100.0
January	0	0	0	0	0	-
February	32.3	0	32.3	0	32.3	100.0
March	8.4	0	8.4	0	8.4	100.0
April	0	0	0	0	0	-
May	16.9	0	16.9	0	16.9	100.0
June	26.7	0	26.7	0	26.7	100.0
July	59.0	0	59.0	0	59.0	100.0
August	80.1	0	80.1	0	80.1	100.0
September	50.6	0	50.6	0	50.6	100.0
ANNUAL TOTALS	334.3	4,636	4,970.0	0	4,970.0	100.0

ASH SLOUGH-WEST NUTRIENT BUDGET

1981-82

INORGANIC N (Kilograms)

Rainfall Loads and Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	7.0	2,318	2,318.0	0	2,318.0	100.0
November	10.6	2,318	2,318.0	0	2,318.0	100.0
December	0	0	0	0	0	-
January	14.1	0	14.1	0	14.1	100.0
February	30.9	0	30.9	0	30.9	100.0
March	21.1	0	21.1	4	17.1	81.0
April	35.0	0	35.0	14	21.0	60.0
May	40.7	0	40.7	0	40.7	100.0
June	77.3	0	77.3	12	65.3	84.5
July	63.2	0	63.2	4	59.2	93.7
August	71.6	0	71.6	1	70.6	98.6
September	88.5	0	88.5	11	77.5	87.6
ANNUAL TOTALS	460.0	4,636	5,096.0	46	5,050.0	99.1

ASH SLOUGH-WEST NUTRIENT BUDGET

1979-80

TOTAL N (Kilograms)

Rainfall Loads and Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer	Total Total N In	Total N Out	Source-/Sink +	%
October	16.1	2,318	2,318.0	64	2,254.0	97.2
November	12.9	2,318	2,318.0	0	2,318.0	100.0
December	54.9	0	54.9	0	54.9	100.0
January	51.7	0	51.7	0	51.7	100.0
February	67.8	0	67.8	34	33.8	49.9
March	71.0	0	71.0	22	49.0	69.0
April	100.2	0	100.2	324	-223.8	-223.4
May	19.3	0	19.3	0	19.3	100.0
June	80.7	0	80.7	0	80.7	100.0
July	232.6	0	232.6	149	83.6	35.9
August	206.6	0	206.6	43	163.3	79.2
September	209.9	0	209.9	263	-53.1	-25.3
ANNUAL TOTALS	1,124.0	4,636	5,760.0	899	4,861.0	84.4

ASH SLOUGH-WEST NUTRIENT BUDGET

1980-81

TOTAL N (Kilograms)

Rainfall Loads and Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer	Total Total N In	Total N Out	Source-/Sink +	%
October	12.9	2,318	2,318.0	0	2,318.0	100.0
November	102.7	2,318	2,318.0	0	2,318.0	100.0
December	22.5	0	22.5	0	22.5	100.0
January	0	0	0	0	0	-
February	74.2	0	74.2	0	74.2	100.0
March	19.3	0	19.3	0	19.3	100.0
April	0	0	0	0	0	-
May	38.8	0	38.8	0	38.8	100.0
June	61.4	0	61.4	0	61.4	100.0
July	135.6	0	135.6	0	135.6	100.0
August	184.1	0	184.1	0	184.1	100.0
September	116.3	0	116.3	9	107.3	92.3
ANNUAL TOTALS	768.4	4,636	5,404.0	9	5,395.0	99.8

ASH SLOUGH-WEST NUTRIENT BUDGET

1981-82

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer	Total Total N In	Total N Out	Source-/Sink +	%
October	16.1	2,318	2,318.0	0	2,318.0	100.0
November	24.4	2,318	2,318.0	0	2,318.0	100.0
December	0	0	0	0	0	-
January	32.4	0	32.4	0	32.4	100.0
February	71.0	0	71.0	0	71.0	100.0
March	48.5	0	48.5	93	-44.5	-91.8
April	80.4	0	80.4	386	-305.6	-380.1
May	93.5	0	93.5	4	89.5	95.7
June	177.7	0	177.7	322	-144.3	-81.2
July	145.3	0	145.3	204	-58.7	-40.4
August	164.6	0	164.6	92	72.6	44.1
September	203.4	0	203.4	161	42.4	20.8
ANNUAL TOTALS	1,057.3	4,636	5,693.0	1,262	4,431.0	77.8

ASH SLOUGH-WEST NUTRIENT BUDGET

1979-80

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	0.63	1,159	1,159.63	17	1,142.63	98.5
November	0.50	1,159	1,159.50	0	1,159.50	100.0
December	2.14	0	2.14	0	2.14	100.0
January	2.01	0	2.01	0	2.01	100.0
February	2.64	0	2.64	68	-65.36	-2,475.8
March	2.77	0	2.77	13	-10.23	-369.3
April	3.90	0	3.90	149	-145.10	-3,702.5
May	0.76	0	0.76	0	0.76	100.0
June	3.15	0	3.15	0	3.15	100.0
July	9.06	0	9.06	74	-64.94	-716.8
August	8.05	0	8.05	25	-16.95	-210.6
September	8.18	0	8.18	119	-110.82	-1,354.8
ANNUAL TOTALS	43.79	2,318	2,362.00	465	1,897.00	80.3

ASH SLOUGH-WEST NUTRIENT BUDGET

1980-81

ORTHO P (Kilograms)

Rainfall Loads and Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	0.50	1,159	1,159	0	1,159	100.0
November	4.02	1,159	1,159	0	1,159	100.0
December	0.88	0	0.88	0	0.88	100.0
January	0	0	0	0	0	-
February	2.89	0	2.89	0	2.89	100.0
March	0.76	0	0.76	0	0.76	100.0
April	0	0	0	0	0	-
May	1.51	0	1.51	0	1.51	100.0
June	2.39	0	2.39	0	2.39	100.0
July	5.28	0	5.28	0	5.28	100.0
August	7.17	0	7.17	0	7.17	100.0
September	4.53	0	4.53	2	2.53	55.8
ANNUAL TOTALS	29.94	2,318	2,348.00	2	2,346.00	99.9

ASH SLOUGH-WEST NUTRIENT BUDGET

1981-82

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer	Total Ortho P In	Ortho P Out	Source-/Sink+	%
October	.63	1,159	1,159	0	1,159	100.0
November	.95	1,159	1,159	0	1,159	100.0
December	0	0	0	0	0	-
January	1.26	0	1.26	0	1.26	100.0
February	2.77	0	2.77	0	2.77	100.0
March	1.89	0	1.89	67	-65.11	-3,445.0
April	3.14	0	3.14	200	-196.86	-6,269.4
May	3.65	0	3.65	1	2.65	72.6
June	6.92	0	6.92	78	-71.08	-1,027.2
July	5.66	0	5.66	29	-23.34	-412.4
August	6.41	0	6.41	9	-2.59	-40.4
September	7.93	0	7.93	17	-9.07	-114.4
ANNUAL TOTALS	41.20	2,318	2,359	401	1,958	83.0

ASH SLOUGH-WEST NUTRIENT BUDGET

1979-80

TOTAL P (Kilograms)

Ranifall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer	Total Total P In	Total P Out	Source-/Sink +	%
October	1.01	1,159	1,160.01	20	1,140.01	98.3
November	.80	1,159	1,159.80	0	1,159.80	100.0
December	3.42	0	3.42	0	3.42	100.0
January	3.22	0	3.22	0	3.22	100.0
February	4.22	0	4.22	73	-68.78	-1,629.9
March	4.43	0	4.43	15	-10.57	-238.6
April	6.24	0	6.24	189	-182.76	-2,928.8
May	1.22	0	1.22	0	1.22	100.0
June	5.04	0	5.04	0	5.04	100.0
July	14.50	0	14.50	86	-71.50	-493.1
August	12.88	0	12.88	28	-15.12	-117.4
September	13.09	0	13.09	132	-118.91	-908.4
ANNUAL TOTALS	70.06	2,318	2,388.00	543	1,845.00	77.3

ASH SLOUGH-WEST NUTRIENT BUDGET

1980-81

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer	Total Total P In	Total P Out	Source-/Sink +	%
October	.80	1,159	1,159.80	0	1,159.80	100.0
November	6.43	1,159	1,165.43	0	1,165.43	100.0
December	1.41	0	1.41	0	1.41	100.0
January	0	0	0	0	0	-
February	4.62	0	4.62	0	4.62	100.0
March	1.22	0	1.22	0	1.22	100.0
April	0	0	0	0	0	-
May	2.42	0	2.42	0	2.42	100.0
June	3.82	0	3.82	0	3.82	100.0
July	8.45	0	8.45	0	8.45	100.0
August	11.47	0	11.47	0	11.47	100.0
September	7.25	0	7.25	2	5.25	72.4
ANNUAL TOTALS	47.90	2,318	2,368.00	2	2,366.00	99.9

ASH SLOUGH-WEST NUTRIENT BUDGET

1981-82

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer	Total Total P	Total P Out	Source-/Sink +	%
October	1.01	1,159	1,160.01	0	1,160.01	100.0
November	1.52	1,159	1,160.52	0	1,160.52	100.0
December	0	0	0	0	0	-
January	2.02	0	2.02	0	2.02	100.0
February	4.43	0	4.43	0	4.43	100.0
March	3.02	0	3.02	70	-66.98	-2,217.9
April	5.02	0	5.02	221	-215.98	-4,302.4
May	5.84	0	5.84	1	4.84	82.9
June	11.07	0	11.07	100	-88.93	-803.3
July	9.06	0	9.06	43	-33.94	-374.6
August	10.26	0	10.26	15	-4.74	-46.2
September	12.69	0	12.69	27	-14.31	-112.8
ANNUAL TOTALS	65.92	2,318	2,384.00	477	1,907.00	80.0

ASH SLOUGH-EAST WATER BUDGET

1979-80

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake+/Discharge-	Percent Net Uptake+/Discharge-
October	3,070	7,096	-4,026	-131.1
November	2,464	0	2,464	100.0
December	10,464	0	10,464	100.0
January	9,858	734	9,124	92.6
February	12,928	6,606	6,322	48.9
March	13,554	2,692	10,862	80.1
April	19,089	1,224	17,865	93.6
May	3,697	0	3,697	100.0
June	15,392	0	15,392	100.0
July	44,339	978	43,361	97.8
August	39,410	978	38,432	97.5
September	40,016	11,256	28,760	71.9
ANNUAL TOTALS	214,282	31,563	182,719	85.3

ASH SLOUGH-EAST WATER BUDGET

1980-81

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake +/Discharge-	Percent Net Uptake +/Discharge-
October	2,464	0	2,464	100.0
November	19,695	0	19,695	100.0
December	4,303	0	4,303	100.0
January	0	0	0	-
February	14,160	0	14,160	100.0
March	3,697	0	3,697	100.0
April	0	0	0	-
May	7,393	0	7,393	100.0
June	11,696	0	11,696	100.0
July	25,856	0	25,856	100.0
August	35,087	0	35,087	100.0
September	22,159	244	21,915	98.9
ANNUAL TOTALS	146,511	244	146,267	99.8

ASH SLOUGH-EAST WATER BUDGET

1981-82

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake+/Discharge-	Percent Net Uptake+/Discharge-
October	3,070	0	3,070	100.0
November	4,626	0	4,626	100.0
December	0	0	0	-
January	6,161	0	6,161	100.0
February	13,554	0	13,554	100.0
March	9,231	244	8,987	97.4
April	15,352	2,692	12,660	82.5
May	17,857	978	16,879	94.5
June	33,855	10,766	23,089	68.2
July	27,714	3,670	24,044	86.8
August	31,391	2,692	28,699	91.4
September	38,784	5,384	33,400	86.1
ANNUAL TOTALS	201,596	26,425	175,171	86.9

ASH SLOUGH-EAST NUTRIENT BUDGET

1979-80

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer	Total Inorganic N In	Inorganic N Out	Source-/Sink+	%
October	2.06	0	2.06	0	2.06	100.0
November	1.65	0	1.65	0	1.65	100.0
December	7.01	0	7.01	0	7.01	100.0
January	6.60	0	6.60	0	6.60	100.0
February	8.66	0	8.66	0	8.66	100.0
March	9.08	0	9.08	0	9.08	100.0
April	12.79	0	12.79	0	12.79	100.0
May	2.48	0	2.48	0	2.48	100.0
June	10.31	0	10.31	0	10.31	100.0
July	29.71	0	29.71	0	29.71	100.0
August	26.40	0	26.40	0	26.40	100.0
September	26.81	0	26.81	0	26.81	100.0
ANNUAL TOTALS	143.60	0	143.60	0	143.60	100.0

ASH SLOUGH-EAST NUTRIENT BUDGET

1980-81

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	1.65	0	1.65	0	1.65	100.0
November	13.20	0	13.20	0	13.20	100.0
December	2.88	0	2.88	0	2.88	100.0
January	0	0	0	0	0	-
February	9.49	0	9.49	0	9.49	100.0
March	2.48	0	2.48	0	2.48	100.0
April	0	0	0	0	0	-
May	4.95	0	4.95	0	4.95	100.0
June	7.84	0	7.84	0	7.84	100.0
July	17.32	0	17.32	0	17.32	100.0
August	23.51	0	23.51	0	23.51	100.0
September	14.85	0	14.85	0	14.85	100.0
ANNUAL TOTALS	96.16	0	98.16	0	98.16	100.0

ASH SLOUGH-EAST NUTRIENT BUDGET

1981-82

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	2.48	0	2.48	0	2.48	100.0
November	11.14	0	11.14	0	11.14	100.0
December	3.71	0	3.71	0	3.71	100.0
January	.83	0	.83	0	.83	100.0
February	7.84	0	7.84	0	7.84	100.0
March	4.53	0	4.53	0	4.53	100.0
April	0	0	0	0	0	-
May	9.49	0	9.49	0	9.49	100.0
June	15.27	0	15.27	0	15.27	100.0
July	15.67	0	15.67	0	15.67	100.0
August	38.77	0	38.77	0	38.77	100.0
September	20.22	0	20.22	0	20.22	100.0
ANNUAL TOTALS	129.94	0	129.94	0	129.94	100.0

ASH SLOUGH-EAST NUTRIENT BUDGET

1979-80

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer	Total Total N In	Total N Out	Source-/Sink +	%
October	4.73	0	4.73	18	-13.27	-280.5
November	3.79	0	3.79	0	3.79	100.0
December	16.11	0	16.11	0	16.11	100.0
January	15.17	0	15.17	2	13.17	86.8
February	19.91	0	19.91	14	5.91	29.7
March	20.87	0	20.87	4	16.87	80.8
April	29.40	0	29.40	2	27.40	93.2
May	5.70	0	5.70	0	5.70	100.0
June	23.70	0	23.70	0	23.70	100.0
July	68.29	0	68.29	2	66.29	97.1
August	60.68	0	60.68	1	59.68	98.4
September	61.62	0	61.62	18	43.62	70.8
ANNUAL TOTALS	330.07	0	300.07	61	269.07	81.5

ASH SLOUGH-EAST NUTRIENT BUDGET

1980-81

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer	Total Total N In	Total N Out	Source-/Sink+	%
October	3.79	0	3.79	0	3.79	100.0
November	30.34	0	30.34	0	30.34	100.0
December	6.62	0	6.62	0	6.62	100.0
January	0	0	0	0	0	-
February	21.81	0	21.81	0	21.81	100.0
March	5.70	0	5.70	0	5.70	100.0
April	0	0	0	0	0	-
May	11.38	0	11.38	0	11.38	100.0
June	18.02	0	18.02	0	18.02	100.0
July	39.81	0	39.81	0	39.81	100.0
August	54.04	0	54.04	0	54.04	100.0
September	34.13	0	34.13	1	33.13	100.0
ANNUAL TOTALS	225.62	0	225.62	1	224.62	99.6

ASH SLOUGH-EAST NUTRIENT BUDGET

1981-82

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Souirce/Sink

Month	Total N In Rainfall	Total N In Fertilizer	Total Total N In	Total N Out	Source-/Sink +	%
October	5.70	0	5.70	0	5.70	100.0
November	25.61	0	25.61	0	25.61	100.0
December	8.53	0	8.53	0	8.53	100.0
January	1.91	0	1.91	0	1.91	100.0
February	18.02	0	18.02	0	18.02	100.0
March	10.41	0	10.41	0	10.41	100.0
April	0	0	0	0	0	-
May	21.81	0	21.81	2	19.81	90.8
June	35.10	0	35.10	18	17.10	48.7
July	36.02	0	36.02	7	29.02	80.6
August	89.11	0	89.11	5	89.11	94.4
September	46.48	0	46.48	9	37.48	80.6
ANNUAL TOTALS	298.67	0	298.67	47	251.67	84.3

ASH SLOUGH-EAST NUTRIENT BUDGET

1979-80

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer	Total Total N In	Total N Out	Source-/Sink +	%
October	0.18	0	0.18	2	-1.82	-1,011.1
November	0.15	0	0.15	0	0.15	100.0
December	0.63	0	0.63	0	0.63	100.0
January	0.59	0	0.59	0	0.59	100.0
February	0.78	0	0.78	2	-1.22	-156.4
March	0.81	0	0.81	1	-0.19	-23.5
April	1.14	0	1.14	1	0.14	12.3
May	0.22	0	0.22	0	0.22	100.0
June	0.93	0	0.93	0	0.93	100.0
July	2.66	0	2.66	0	2.66	100.0
August	2.36	0	2.36	0	2.36	100.0
September	2.40	0	2.40	3	-0.60	-25.0
ANNUAL TOTALS	12.86	0	12.86	9	3.86	30.0

ASH SLOUGH-EAST NUTRIENT BUDGET

1980-81

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer	Total Ortho P In	Ortho P Out	Source-/Sink+	%
October	0.15	0	0.15	0	0.15	100.0
November	1.18	0	1.18	0	1.18	100.0
December	0.26	0	0.26	0	0.26	100.0
January	0	0	0	0	0	-
February	0.85	0	0.85	0	0.85	100.0
March	0.22	0	0.22	0	0.22	100.0
April	0	0	0	0	0	-
May	0.44	0	0.44	0	0.44	100.0
June	0.70	0	0.70	0	0.70	100.0
July	1.55	0	1.55	0	1.55	100.0
August	2.11	0	2.11	0	2.11	100.0
September	1.33	0	1.33	0	1.33	100.0
ANNUAL TOTALS	8.79	0	8.79	0	8.79	100.0

ASH SLOUGH-EAST NUTRIENT BUDGET

1981-82

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	0.22	0	0.22	0	0.22	100.0
November	1.00	0	1.00	0	1.00	100.0
December	0.33	0	0.33	0	0.33	100.0
January	0.08	0	0.08	0	0.08	100.0
February	0.70	0	0.70	0	0.70	100.0
March	0.41	0	0.41	0	0.41	100.0
April	0	0	0	1	-1.00	-
May	0.85	0	0.85	0	0.85	100.0
June	1.37	0	1.37	2	-0.63	-46.0
July	1.41	0	1.41	0	1.41	100.0
August	3.48	0	3.48	0	3.48	100.0
September	1.81	0	1.81	0	1.81	100.0
ANNUAL TOTALS	11.64	0	11.64	3	8.64	74.2

ASH SLOUGH-EAST NUTRIENT BUDGET

1979-80

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer	Total Total P In	Total P Out	Source-/Sink+	%
October	0.29	0	0.29	3	-2.71	-934.5
November	0.24	0	0.24	0	0.24	100.0
December	1.00	0	1.00	0	1.00	100.0
January	0.95	0	0.95	0	0.95	100.0
February	1.24	0	1.24	3	-1.76	-141.9
March	1.30	0	1.30	1	0.30	23.1
April	1.83	0	1.83	1	0.83	45.4
May	0.35	0	0.35	0	0.35	100.0
June	1.48	0	1.48	0	1.48	100.0
July	4.26	0	4.26	0	4.26	100.0
August	3.78	0	3.78	0	3.78	100.0
September	3.84	0	3.84	4	-0.16	-4.2
ANNUAL TOTALS	20.57	0	20.57	12	8.57	41.7

ASH SLOUGH-EAST NUTRIENT BUDGET

1980-81

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer	Total Total P In	Total P Out	Source-/Sink +	%
October	0.24	0	0.24	0	0.24	100.0
November	1.89	0	1.89	0	1.89	100.0
December	0.41	0	0.41	0	0.41	100.0
January	0	0	0	0	0	-
February	1.36	0	1.36	0	1.36	100.0
March	0.35	0	0.35	0	0.35	100.0
April	0	0	0	0	0	-
May	0.71	0	0.71	0	0.71	100.0
June	1.12	0	1.12	0	1.12	100.0
July	2.48	0	2.48	0	2.48	100.0
August	3.37	0	3.37	0	3.37	100.0
September	2.13	0	2.13	0	2.13	100.0
ANNUAL TOTALS	14.07	0	14.07	0	14.07	100.0

ASH SLOUGH-EAST NUTRIENT BUDGET

1981-82

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer	Total Total P In	Total P Out	Source-/Sink+	%
October	0.35	0	0.35	0	0.35	100.0
November	1.60	0	1.60	0	1.60	100.0
December	0.53	0	0.53	0	0.53	100.0
January	0.12	0	0.12	0	0.12	100.0
February	1.12	0	1.12	0	1.12	100.0
March	0.65	0	0.65	0	0.65	100.0
April	0	0	0	1	-1.00	-
May	1.36	0	1.36	0	1.36	100.0
June	2.19	0	2.19	3	-0.81	-37.0
July	2.25	0	2.25	0	2.25	100.0
August	5.56	0	5.56	0	5.56	100.0
September	2.90	0	2.90	0	2.90	100.0
ANNUAL TOTALS	18.62	0	18.62	4	14.62	78.5

PEAVINE PASTURE WATER BUDGET

1979-80

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake + /Discharge-	Percent Net Uptake + /Discharge-
October	0	172,213	-172,213	-
November	29,605	2,961	26,644	90.0
December	44,407	0	44,407	100.0
January	66,611	987	65,624	98.5
February	59,201	25,413	33,788	57.1
March	51,808	11,966	39,842	76.9
April	88,814	1,974	86,840	97.8
May	296,047	1,234	294,813	99.6
June	177,628	0	177,628	100.0
July	392,262	1,234	391,028	99.7
August	149,023	82,159	65,864	44.5
September	29,605	2,467	27,138	91.7
ANNUAL TOTALS	1,384,011	302,608	1,081,403	78.1

PEAVINE PASTURE WATER BUDGET

1980-81

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake+/Discharge-	Percent Net Uptake+/Discharge-
October	22,204	0	22,204	100.0
November	155,425	0	155,425	100.0
December	96,215	0	96,215	100.0
January	0	0	0	-
February	140,622	0	140,622	100.0
March	103,616	0	103,616	100.0
April	0	0	0	-
May	103,616	0	103,616	100.0
June	155,425	493	154,932	99.7
July	244,239	987	243,252	99.6
August	362,657	66,122	296,535	81.8
September	347,855	634,204	-286,349	-82.3
ANNUAL TOTALS	1,731,874	701,806	1,030,068	59.5

PEAVINE PASTURE WATER BUDGET

1981-82

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake +/Discharge-	Percent Net Uptake +/Discharge-
October	103,616	24,672	78,944	76.2
November	192,430	42,066	150,364	78.1
December	0	0	0	-
January	59,209	0	59,209	100.0
February	51,808	2,221	49,587	95.7
March	199,832	37,872	161,960	81.0
April	244,239	197,502	46,737	19.1
May	333,053	68,713	264,340	79.4
June	310,849	461,250	-150,401	-48.4
July	431,735	466,555	-34,820	-8.1
August	370,058	383,902	-13,844	-3.7
September	573,591	584,982	-11,391	-2.0
ANNUAL TOTALS	2,870,420	2,269,735	600,685	20.9

PEAVINE PASTURE NUTRIENT BUDGET

1979-80

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	0	0	0	2.76	-2.76	-
November	19.84	0	19.84	.05	19.79	99.7
December	29.75	0	29.75	0	29.75	100.0
January	44.63	0	44.63	.05	44.58	99.9
February	39.66	0	39.66	.25	39.41	99.4
March	34.71	0	34.71	.12	34.59	99.7
April	59.51	7,040	7,099.51	.05	7,099.46	100.0
May	198.35	7,040	7,238.35	.02	7,238.33	100.0
June	119.01	7,040	7,159.01	0	7,159.01	100.0
July	262.82	0	262.82	.02	262.80	100.0
August	99.18	0	99.18	1.45	97.73	98.5
September	19.84	0	19.84	.05	19.79	99.7
ANNUAL TOTALS	927.30	21,120	22,047.00	4.82	22,042.00	100.0

PEAVINE PASTURE NUTRIENT BUDGET

1980-81

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	14.88	0	14.88	0	14.88	100.0
November	104.13	0	104.13	0	104.13	100.0
December	64.46	0	64.46	0	64.46	100.0
January	0	0	0	0	0	-
February	94.22	0	94.22	0	94.22	100.0
March	69.42	0	69.42	0	69.42	100.0
April	0	7,040	7,040.00	0	7,040.00	100.0
May	69.42	7,040	7,109.42	0	7,109.42	100.0
June	104.13	7,040	7,144.13	.03	7,144.10	100.0
July	163.64	0	163.64	.04	163.60	100.0
August	242.98	0	242.98	2.29	240.69	99.1
September	233.06	0	233.06	19.03	214.03	91.8
ANNUAL TOTALS	1,160.34	21,120	22,280.00	21.39	22,259.00	99.9

PEAVINE PASTURE NUTRIENT BUDGET

1981-82

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	69.42	0	69.42	.50	68.92	99.3
November	128.93	0	128.93	1.46	127.47	98.9
December	0	0	0	0	0	-
January	39.67	0	39.67	0	39.67	100.0
February	34.71	0	34.71	.04	34.67	99.9
March	133.89	0	133.89	1.20	132.69	99.1
April	163.64	7,040	7,203.64	6.04	7,197.60	99.9
May	223.16	7,040	7,263.15	1.59	7,261.56	100.0
June	208.27	7,040	7,248.27	10.90	7,237.80	99.9
July	289.26	0	289.26	9.33	279.93	96.8
August	247.94	0	247.94	8.39	239.55	96.6
September	384.31	0	384.31	9.79	374.52	97.5
ANNUAL TOTALS	1,923.19	21,120	23,043	49.24	22,994.00	99.8

PEAVINE PASTURE NUTRIENT BUDGET

1979-80

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer	Total Total N In	Total N Out	Source-/Sink +	%
October	0	0	0	239.97	-238.97	0
November	45.59	0	45.59	4.03	41.56	91.2
December	68.39	0	68.39	0	68.39	100.0
January	102.58	0	102.58	2.24	100.34	97.8
February	91.17	0	91.17	43.96	47.21	51.8
March	79.78	0	79.78	20.81	58.97	73.9
April	136.77	7,040	7,177.00	3.92	7,173.08	99.9
May	455.91	7,040	7,496.00	2.28	7,493.72	100.0
June	273.55	7,040	7,314.00	0	7,314.00	100.0
July	604.08	0	604.08	2.16	601.82	99.7
August	227.96	0	227.96	142.82	85.14	37.3
September	45.59	0	45.59	3.84	41.75	91.6
ANNUAL TOTALS	2,137.37	21,120	23,257.00	465.03	22,792.00	98.0

PEAVINE PASTURE NUTRIENT BUDGET

1980-81

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer	Total Total N In	Total N Out	Source-/Sink +	%
October	34.19	0	34.19	0	34.19	100.0
November	239.35	0	239.35	0	239.35	100.0
December	148.17	0	148.17	0	148.17	100.0
January	0	0	0	0	0	-
February	216.56	0	216.56	0	216.56	100.0
March	159.57	0	159.57	0	159.57	100.0
April	0	7,040	7,040.00	0	7,040.00	100.0
May	159.57	7,040	7,200.00	0	7,200.00	100.0
June	239.35	7,040	7,279.00	1.09	7,277.91	100.0
July	376.13	0	376.13	2.88	373.25	99.2
August	558.49	0	558.49	159.38	399.11	71.5
September	535.70	0	535.70	1,459.16	-923.46	-172.4
ANNUAL TOTALS	2,667.08	21,120	23,787.00	1,622.51	22,165.00	93.2

PEAVINE PASTURE NUTRIENT BUDGET

1981-82

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer	Total Total N In	Total N Out	Source-/Sink +	%
October	159.57	0	159.57	68.34	91.23	57.2
November	296.34	0	296.34	91.20	205.14	69.2
December	0	0	0	0	0	-
January	91.18	0	91.18	0	91.18	100.0
February	79.78	0	79.78	5.37	74.41	93.3
March	307.74	0	307.74	98.74	209.00	67.9
April	314.54	7,040	7,355.00	425.35	6,929.65	94.2
May	512.90	7,040	7,553.00	151.91	7,401.09	98.0
June	478.71	7,040	7,519.00	994.44	6,524.56	86.8
July	664.87	0	664.87	694.47	-29.60	-4.5
August	569.89	0	569.89	618.66	-48.77	-8.6
September	883.33	0	883.33	694.93	188.40	21.3
ANNUAL TOTALS	4,358.84	21,120	21,579.00	3,843.41	17,736.00	82.2

PEAVINE PASTURE NUTRIENT BUDGET

1979-80

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	0	0	0	1.70	-1.70	-
November	1.78	0	1.78	.03	1.75	98.3
December	2.66	0	2.66	0	2.66	100.0
January	4.00	0	4.00	.01	3.99	99.8
February	3.55	0	3.55	.25	3.30	93.0
March	3.11	0	3.11	.12	2.99	96.1
April	5.33	1,760	1,765.53	.02	1,765.31	100.0
May	17.76	1,760	1,777.76	.01	1,777.75	100.0
June	10.66	1,760	1,770.66	0	1,770.66	100.0
July	23.54	0	23.54	.01	23.54	100.0
August	8.88	0	8.88	.82	8.06	90.8
September	1.78	0	1.78	.02	1.76	98.9
ANNUAL TOTALS	83.85	5,280	5,364.00	2.99	5,361.00	99.9

PEAVINE PASTURE NUTRIENT BUDGET

1980-81

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	1.33	0	1.33	0	1.33	100.0
November	9.33	0	9.33	0	9.33	100.0
December	5.77	0	5.77	0	5.77	100.0
January	0	0	0	0	0	-
February	8.44	0	8.44	0	8.44	100.0
March	6.22	0	6.22	0	6.22	100.0
April	0	1,760	1,760.00	0	1,760.00	100.0
May	6.22	1,760	1,766.22	0	1,766.22	100.0
June	9.33	1,760	1,769.33	.02	1,769.31	100.0
July	14.65	0	14.65	.08	14.57	99.5
August	21.76	0	21.76	2.03	19.73	90.7
September	20.87	0	20.87	15.96	4.91	23.5
ANNUAL TOTALS	103.92	5,280	5,384.00	18.09	5,366.00	99.7

PEAVINE PASTURE NUTRIENT BUDGET

1981-82

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	6.22	0	6.22	.92	6.30	85.2
November	11.55	0	11.55	.60	10.95	94.8
December	0	0	0	0	0	-
January	3.55	0	3.55	0	3.55	100.0
February	3.11	0	3.11	.12	2.99	96.1
March	11.99	0	11.99	.43	11.45	96.4
April	14.65	1,760	1,774.65	1.15	1,773.50	99.9
May	19.98	1,760	1,779.98	.30	1,779.68	100.0
June	18.55	1,760	1,778.65	3.52	1,775.13	99.8
July	25.90	0	25.90	3.18	22.72	87.7
August	22.20	0	22.20	1.54	20.66	93.1
September	34.42	0	34.42	2.34	32.08	93.2
ANNUAL TOTALS	172.22	5,280	5,452.00	14.10	54.38	99.7

PEAVINE PASTURE NUTRIENT BUDGET

1979-80

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer	Total Total P In	Total P Out	Source-/Sink +	%
October	0	0	0	5.87	-5.87	-
November	2.84	0	2.84	.12	2.72	95.8
December	4.26	0	4.26	0	4.26	100.0
January	6.39	0	6.39	.09	6.30	98.6
February	5.68	0	5.68	.66	5.02	88.4
March	4.97	0	4.97	.29	4.68	94.2
April	8.53	1,760	1,768.53	-.09	1,768.44	100.0
May	28.42	1,760	1,788.42	-.08	1,788.34	100.0
June	17.05	1,760	1,777.05	0	1,777.05	100.0
July	37.66	0	37.66	.04	37.62	99.9
August	14.21	0	14.21	2.30	11.91	83.8
September	2.84	0	2.84	.07	2.77	97.5
ANNUAL TOTALS	132.85	5,280	5,413.00	9.61	5,403.00	99.8

PEAVINE PASTURE NUTRIENT BUDGET

1980-81

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer	Total Total P In	Total P Out	Source-/Sink +	%
October	2.13	0	2.13	0	2.13	100.0
November	14.92	0	14.82	0	14.92	100.0
December	9.24	0	9.24	0	9.24	100.0
January	0	0	0	0	0	-
February	13.50	0	13.50	0	13.50	100.0
March	9.95	0	9.95	0	9.95	100.0
April	0	1,760	1,760.00	0	1,760.00	100.0
May	9.95	1,760	1,769.95	0	1,769.95	100.0
June	14.92	1,760	1,744.92	-.05	1,774.87	100.0
July	23.45	0	23.45	.14	23.30	99.4
August	34.82	0	34.82	7.14	27.68	79.5
September	33.39	0	33.39	63.37	-29.98	-89.8
ANNUAL TOTALS	166.27	5,280	5,446.00	70.71	5,375.00	98.7

PEAVINE PASTURE NUTRIENT BUDGET

1981-82

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer	Total Total P In	Total P Out	Source-/Sink +	%
October	9.95	0	9.95	2.39	7.56	76.0
November	18.47	0	18.47	1.68	16.79	90.9
December	0	0	0	0	0	-
January	5.68	0	5.68	0	5.68	100.0
February	4.97	0	4.97	.24	4.73	95.2
March	19.18	0	19.18	2.36	16.82	87.7
April	23.45	1,760	1,783.45	-7.00	1,776.45	99.6
May	31.97	1,760	1,791.97	-2.64	1,789.33	99.9
June	29.84	1,760	1,789.84	-20.93	1,768.91	98.8
July	41.45	0	41.45	17.88	23.57	56.9
August	35.53	0	35.53	12.34	23.19	65.3
September	55.06	0	55.06	13.63	41.43	75.2
ANNUAL TOTALS	275.55	5,280	5,556.00	81.09	5,475.00	98.5

LYKES WATER BUDGET

WEST WATERSHED

1979-80

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake +/Discharge-	Percent Net Uptake +/Discharge-
October	368,729	398,526	-29,373	-8.0
November	105,351	77,809	27,542	26.1
December	526,755	19,819	506,936	96.2
January	1,264,213	33,033	1,231,180	97.4
February	737,458	94,204	643,254	87.2
March	842,809	78,299	764,510	90.7
April	948,160	5,384	942,776	99.4
May	1,422,240	0	1,422,240	100.0
June	1,369,564	0	1,369,564	100.0
July	2,739,128	0	2,739,128	100.0
August	1,474,915	0	1,474,915	100.0
September	948,160	0	948,160	100.0
ANNUAL TOTALS	12,747,481	706,650	12,040,831	94.5

LYKES WATER BUDGET

WEST WATERSHED

1980-81

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake +/Discharge-	Percent Net Uptake +/Discharge-
October	210,702	0	210,702	100.0
November	1,422,240	0	1,422,240	100.0
December	316,053	0	316,053	100.0
January	52,676	0	52,676	100.0
February	1,053,511	0	1,053,511	100.0
March	316,053	0	316,053	100.0
April	52,676	0	52,676	100.0
May	1,000,835	0	1,000,835	100.0
June	2,528,426	0	2,528,426	100.0
July	3,897,990	0	3,897,990	100.0
August	2,686,453	499,891	2,186,562	81.4
September	1,474,915	112,066	1,362,849	92.4
ANNUAL TOTALS	15,012,529	611,957	14,400,572	95.9

LYKES WATER BUDGET

WEST WATERSHED

1981-82

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake+/Discharge-	Percent Net Uptake+/Discharge-
October	316,053	0	316,053	100.0
November	474,080	0	474,080	100.0
December	0	0	0	-
January	1,106,186	0	1,106,186	100.0
February	1,211,537	0	1,211,537	100.0
March	3,002,506	0	3,002,506	100.0
April	1,948,995	0	1,948,995	100.0
May	1,580,266	0	1,580,266	100.0
June	3,529,261	140,449	3,338,812	96.0
July	1,790,968	151,704	1,639,264	91.5
August	1,580,266	113,044	1,467,222	92.8
September	1,211,537	0	1,211,537	100.0
ANNUAL TOTALS	17,751,657	405,197	17,346,460	97.7

LYKES NUTRIENT BUDGET

WEST WATERSHED

1979-80

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	247	0	247	16	231	93.5
November	70	0	70	6	64	91.4
December	353	0	353	7	346	98.0
January	847	0	847	6	841	99.3
February	494	0	494	3	491	99.4
March	565	0	565	4	561	99.3
April	635	0	635	1	634	99.8
May	953	0	953	0	953	100.0
June	918	0	918	0	918	100.0
July	1,835	0	1,835	0	1,835	100.0
August	988	0	988	0	988	100.0
September	635	0	635	0	635	100.0
ANNUAL TOTALS	8,541	0	8,541	53	8,488	99.4

LYKES NUTRIENT BUDGET

WEST WATERSHED

1980-81

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	141	0	141	0	141	100.0
November	953	0	953	0	953	100.0
December	212	0	212	0	212	100.0
January	35	0	35	0	35	100.0
February	706	0	706	0	706	100.0
March	212	0	212	0	212	100.0
April	35	0	35	0	35	100.0
May	670	0	670	0	670	100.0
June	1,694	0	1,694	0	1,694	100.0
July	2,612	0	2,612	0	2,612	100.0
August	1,800	0	1,800	32	1,768	98.2
September	988	0	988	8	980	99.2
ANNUAL TOTALS	10,058	0	10,058	40	10,018	99.6

LYKES NUTRIENT BUDGET

WEST WATERSHED

1981-82

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	212	0	212	0	212	100.0
November	318	0	318	0	318	100.0
December	0	0	0	0	0	-
January	741	0	741	0	741	100.0
February	812	0	812	0	812	100.0
March	2,012	0	2,012	0	2,012	100.0
April	1,307	0	1,307	0	1,307	100.0
May	1,059	0	1,059	0	1,059	100.0
June	2,365	0	2,365	4	2,361	99.8
July	1,200	0	1,200	5	1,195	99.6
August	1,059	0	1,059	4	1,055	99.6
September	812	0	812	0	812	100.0
ANNUAL TOTALS	11,894	0	11,894	13	11,881	99.9

LYKES NUTRIENT BUDGET

WEST WATERSHED

1979-80

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer	Total Total N In	Total N Out	Source-/Sink +	%
October	568	0	568	748	-180	-31.7
November	162	0	162	174	-12	-7.4
December	811	0	811	69	742	91.5
January	1,947	0	1,947	101	1,846	94.8
February	1,136	0	1,136	412	724	63.7
March	1,298	0	1,298	558	740	57.0
April	1,460	0	1,460	18	1,442	98.8
May	2,190	0	2,190	0	2,190	100.0
June	2,109	0	2,109	0	2,109	100.0
July	4,218	0	4,218	0	4,218	100.0
August	2,271	0	2,271	0	2,271	100.0
September	1,460	0	1,460	0	1,460	100.0
ANNUAL TOTALS	19,631	0	19,631	2,080	17,551	89.4

LYKES NUTRIENT BUDGET

WEST WATERSHED

1980-81

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer	Total Total N In	Total N Out	Source-/Sink+	%
October	324	0	324	0	324	100.0
November	2,190	0	2,190	0	2,190	100.0
December	487	0	487	0	487	100.0
January	81	0	81	0	81	100.0
February	1,622	0	1,622	0	1,622	100.0
March	487	0	487	0	487	100.0
April	81	0	81	0	81	100.0
May	1,541	0	1,541	0	1,541	100.0
June	3,894	0	3,894	0	3,894	100.0
July	6,003	0	6,003	0	6,003	100.0
August	4,137	0	4,137	1,197	2,940	71.1
September	2,271	0	2,271	280	1,991	87.7
ANNUAL TOTALS	23,119	0	23,119	1,477	21,641	93.6

LYKES NUTRIENT BUDGET

WEST WATERSHED

1981-82

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer	Total Total N In	Total N Out	Source-/Sink+	%
October	487	0	487	0	487	100.0
November	730	0	730	0	730	100.0
December	0	0	0	0	0	-
January	1,704	0	1,704	0	1,704	100.0
February	1,866	0	1,866	0	1,866	100.0
March	4,624	0	4,624	0	4,624	100.0
April	3,001	0	3,001	0	3,001	100.0
May	2,434	0	2,434	0	2,434	100.0
June	5,435	0	5,435	351	5,084	93.5
July	2,758	0	2,758	370	2,388	86.6
August	2,434	0	2,434	362	2,072	85.1
September	1,866	0	1,866	0	1,866	100.0
ANNUAL TOTALS	27,388	0	27,338	1,083	26,255	96.0

LYKES NUTRIENT BUDGET

WEST WATERSHED

1979-80

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	22	0	22	4	18	81.8
November	6	0	6	1	5	83.3
December	32	0	32	1	31	96.9
January	76	0	76	1	75	98.7
February	44	0	44	1	43	97.7
March	51	0	51	1	50	98.0
April	57	0	57	0	57	100.0
May	86	0	86	0	86	100.0
June	82	0	82	0	82	100.0
July	164	0	164	0	164	100.0
August	89	0	89	0	89	100.0
September	57	0	57	0	57	100.0
ANNUAL TOTALS	765	0	765	9	756	98.8

LYKES NUTRIENT BUDGET

WEST WATERSHED

1980-81

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	13	0	13	0	13	100.0
November	86	0	86	0	86	100.0
December	19	0	19	0	19	100.0
January	3	0	3	0	3	100.0
February	63	0	63	0	63	100.0
March	19	0	19	0	19	100.0
April	3	0	3	0	3	100.0
May	60	0	60	0	60	100.0
June	152	0	152	0	152	100.0
July	234	0	234	0	234	100.0
August	161	0	161	5	156	96.9
September	89	0	89	1	88	98.9
ANNUAL TOTALS	901	0	901	6	895	99.3

LYKES NUTRIENT BUDGET

WEST WATERSHED

1981-82

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	19	0	19	0	19	100.0
November	29	0	29	0	29	100.0
December	0	0	0	0	0	-
January	66	0	66	0	66	100.0
February	73	0	73	0	73	100.0
March	180	0	180	0	180	100.0
April	117	0	117	0	117	100.0
May	95	0	95	0	95	100.0
June	212	0	212	1	211	99.5
July	108	0	108	1	107	99.1
August	95	0	95	0	95	100.0
September	73	0	73	0	73	100.0
ANNUAL TOTALS	1,065	0	1,065	2	1,063	99.8

LYKES NUTRIENT BUDGET

WEST WATERSHED

1979-80

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer	Total Total P In	Total P Out	Source-/Sink +	%
October	35	0	35	8	27	77.1
November	10	0	10	2	8	80.0
December	51	0	51	2	49	96.1
January	121	0	121	3	118	97.5
February	71	0	71	25	46	64.8
March	81	0	81	39	42	51.9
April	91	0	91	1	90	98.9
May	137	0	137	0	137	100.0
June	131	0	131	0	131	100.0
July	263	0	263	0	263	100.0
August	142	0	142	0	142	100.0
September	91	0	91	0	91	100.0
ANNUAL TOTALS	1,224	0	1,224	80	1,144	93.5

LYKES NUTRIENT BUDGET

WEST WATERSHED

1980-81

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer	Total Total P In	Total P Out	Source-/Sink +	%
October	20	0	20	0	20	100.0
November	137	0	137	0	137	100.0
December	30	0	30	0	30	100.0
January	5	0	5	0	5	100.0
February	101	0	101	0	101	100.0
March	30	0	30	0	30	100.0
April	5	0	5	0	5	100.0
May	96	0	96	0	96	100.0
June	243	0	243	0	243	100.0
July	374	0	374	0	374	100.0
August	258	0	258	44	214	82.9
September	142	0	142	10	132	93.0
ANNUAL TOTALS	1,441	0	1,441	54	1,387	96.3

LYKES NUTRIENT BUDGET

WEST WATERSHED

1981-82

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer	Total Total P In	Total P Out	Source-/Sink +	%
October	30	0	30	0	30	100.0
November	46	0	46	0	46	100.0
December	0	0	0	0	0	-
January	106	0	106	0	106	100.0
February	116	0	116	0	116	100.0
March	288	0	288	0	288	100.0
April	187	0	187	0	187	100.0
May	152	0	152	0	152	100.0
June	339	0	339	9	330	97.3
July	172	0	172	8	164	95.3
August	152	0	152	7	145	95.4
September	116	0	116	0	116	100.0
ANNUAL TOTALS	1,704	0	1,704	24	1,680	98.6

LYKES WATER BUDGET

EAST WATERSHED

1979-80

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake+/Discharge-	Percent Net Uptake+/Discharge-
October	552,661	2,102,576	-1,549,915	280.4
November	157,903	59,458	98,445	62.3
December	789,516	39,884	749,632	94.9
January	1,894,839	52,852	1,841,987	97.2
February	1,105,323	127,725	977,598	88.4
March	1,263,226	27,405	1,235,821	97.8
April	1,421,129	18,841	1,402,288	98.7
May	2,131,694	1,224	2,130,470	99.9
June	2,052,742	0	2,052,742	100.0
July	4,105,485	12,479	4,093,006	99.7
August	2,210,646	0	2,210,646	100.0
September	1,421,129	6,852	1,414,277	99.5
ANNUAL TOTALS	19,106,294	2,449,296	16,656,998	87.2

LYKES WATER BUDGET

EAST WATERSHED

1980-81

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake+/Discharge-	Percent Net Uptake+/Discharge-
October	315,807	0	315,807	100.0
November	2,131,694	0	2,131,694	100.0
December	473,710	0	473,710	100.0
January	78,952	0	78,952	100.0
February	1,579,033	0	1,579,033	100.0
March	473,710	0	473,710	100.0
April	78,952	0	78,952	100.0
May	1,500,081	0	1,500,081	100.0
June	3,789,678	0	3,789,678	100.0
July	5,842,421	10,032	5,832,389	99.8
August	4,026,533	436,273	3,590,260	89.2
September	2,210,646	909,493	1,301,153	58.9
ANNUAL TOTALS	22,501,214	1,355,798	21,145,416	94.0

LYKES WATER BUDGET

EAST WATERSHED

1981-82

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake+/Discharge-	Percent Net Uptake+/Discharge-
October	473,710	106,682	367,028	77.5
November	710,565	1,958	708,607	99.7
December	0	0	0	-
January	1,657,984	0	1,657,984	100.0
February	1,815,887	0	1,815,887	100.0
March	4,500,243	5,628	4,494,615	99.9
April	2,921,210	3,670	2,917,540	99.9
May	2,368,549	3,916	2,364,633	99.8
June	5,289,759	1,483,034	3,806,725	72.0
July	2,684,355	676,553	2,007,802	74.8
August	2,368,549	1,034,711	1,333,778	56.3
September	1,815,887	201,131	1,614,756	88.9
ANNUAL TOTALS	26,606,699	3,517,343	23,089,356	86.8

LYKES NUTRIENT BUDGET

EAST WATERSHED

1979-80

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	370	0	370	21	349	94.3
November	106	0	106	1	105	99.1
December	529	0	529	1	528	99.8
January	1,270	0	1,270	1	1,269	99.9
February	740	0	740	2	738	99.7
March	846	0	846	0	846	100.0
April	952	0	952	0	952	100.0
May	1,428	0	1,428	0	1,428	100.0
June	1,375	0	1,375	0	1,375	100.0
July	2,750	0	2,750	0	2,750	100.0
August	1,481	0	1,481	0	1,481	100.0
September	952	0	952	0	952	100.0
ANNUAL TOTALS	12,801	0	12,801	26	12,775	99.8

LYKES NUTRIENT BUDGET

EAST WATERSHED

1980-81

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	211	0	211	0	211	100.0
November	1,428	0	1,428	0	1,428	100.0
December	318	0	318	0	318	100.0
January	53	0	53	0	53	100.0
February	1,058	0	1,058	0	1,058	100.0
March	318	0	318	0	318	100.0
April	53	0	53	0	53	100.0
May	1,005	0	1,005	0	1,005	100.0
June	2,539	0	2,539	0	2,539	100.0
July	3,914	0	3,914	2	3,912	99.9
August	2,698	0	2,698	11	2,687	99.6
September	1,481	0	1,481	29	1,452	98.0
ANNUAL TOTALS	15,076	0	15,076	42	15,034	99.7

LYKES NUTRIENT BUDGET

EAST WATERSHED

1981-82

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	318	0	318	4	314	98.7
November	476	0	476	0	476	100.0
December	0	0	0	0	0	-
January	1,111	0	1,111	0	1,111	100.0
February	1,216	0	1,216	0	1,216	100.0
March	3,015	0	3,015	0	3,015	100.0
April	1,957	0	1,957	0	1,957	100.0
May	1,587	0	1,587	2	1,585	99.9
June	3,544	0	3,544	25	3,519	99.3
July	1,799	0	1,799	18	1,781	99.0
August	1,587	0	1,587	43	1,544	97.3
September	1,216	0	1,216	8	1,208	99.3
ANNUAL TOTALS	17,826	0	17,826	100	17,726	99.4

LYKES NUTRIENT BUDGET

EAST WATERSHED

1979-80

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer	Total Total N In	Total N Out	Source-/Sink+	%
October	851	0	851	2,018	-1,167	-137.1
November	243	0	243	90	153	63.0
December	1,216	0	1,216	62	1,154	5.1
January	2,918	0	2,918	66	2,852	97.7
February	1,702	0	1,702	193	1,509	88.7
March	1,945	0	1,945	50	1,895	97.4
April	2,189	0	2,189	35	2,154	98.4
May	3,283	0	3,283	2	3,281	99.9
June	3,161	0	3,161	0	3,161	100.0
July	6,322	0	6,322	15	6,307	99.8
August	3,404	0	3,404	0	3,404	100.0
September	2,189	0	2,189	12	2,177	99.5
ANNUAL TOTALS	29,424	0	29,424	2,543	26,881	91.4

LYKES NUTRIENT BUDGET

EAST WATERSHED

1980-81

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer	Total Total N In	Total N Out	Source-/Sink +	%
October	486	0	486	0	486	100.0
November	3,283	0	3,283	0	3,283	100.0
December	730	0	730	0	730	100.0
January	122	0	122	0	122	100.0
February	2,432	0	2,432	0	2,432	100.0
March	730	0	730	0	730	100.0
April	122	0	122	0	122	100.0
May	2,310	0	2,310	0	2,310	100.0
June	5,836	0	5,836	0	5,836	100.0
July	8,997	0	8,997	19	8,978	99.8
August	6,201	0	6,201	835	5,366	86.5
September	3,404	0	3,404	1,729	1,675	49.2
ANNUAL TOTALS	34,652	0	34,652	2,583	32,069	92.5

LYKES NUTRIENT BUDGET

EAST WATERSHED

1981-82

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer	Total Total N In	Total N Out	Source-/Sink +	%
October	730	0	730	216	514	70.4
November	1,094	0	1,094	3	1,091	99.7
December	0	0	0	0	0	-
January	2,553	0	2,553	0	2,553	100.0
February	2,796	0	2,796	0	2,796	100.0
March	6,930	0	6,930	14	6,916	99.8
April	4,499	0	4,499	7	4,492	99.8
May	3,648	0	3,648	12	3,636	99.7
June	8,146	0	8,146	2,506	5,640	69.2
July	4,134	0	4,134	1,142	2,992	72.4
August	3,648	0	3,648	1,762	1,886	51.7
September	2,796	0	2,796	453	2,343	83.8
ANNUAL TOTALS	40,974	0	40,974	6,115	34,859	85.1

LYKES NUTRIENT BUDGET

EAST WATERSHED

1979-80

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	33	0	33	32	1	3.0
November	9	0	9	1	8	88.9
December	48	0	48	1	47	97.9
January	114	0	114	1	113	99.1
February	66	0	66	1	65	98.5
March	76	0	76	0	76	100.0
April	85	0	85	0	85	100.0
May	128	0	128	0	128	100.0
June	123	0	123	0	123	100.0
July	246	0	246	0	246	100.0
August	133	0	133	0	133	100.0
September	85	0	85	0	85	100.0
ANNUAL TOTALS	1,146	0	1,146	36	1,110	96.9

LYKES NUTRIENT BUDGET

EAST WATERSHED

1980-81

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	19	0	9	0	19	100.0
November	128	0	128	0	128	100.0
December	28	0	28	0	28	100.0
January	5	0	5	0	5	100.0
February	95	0	95	0	95	100.0
March	28	0	28	0	28	100.0
April	5	0	5	0	5	100.0
May	90	0	90	0	90	100.0
June	228	0	228	0	228	100.0
July	351	0	351	0	351	100.0
August	242	0	242	4	238	98.3
September	133	0	133	0	133	100.0
ANNUAL TOTALS	1,350	0	1,350	4	1,346	99.7

LYKES NUTRIENT BUDGET

EAST WATERSHED

1981-82

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	28	0	28	14	14	50.0
November	43	0	43	3	40	93.0
December	0	0	0	0	0	-
January	99	0	99	0	99	100.0
February	109	0	109	0	109	100.0
March	270	0	270	0	270	100.0
April	175	0	175	0	175	100.0
May	142	0	142	0	142	100.0
June	318	0	318	7	311	97.8
July	161	0	161	3	158	98.1
August	142	0	142	4	138	97.2
September	109	0	109	1	108	99.1
ANNUAL TOTALS	1,596	0	1,596	32	1,564	98.0

LYKES NUTRIENT BUDGET

EAST WATERSHED

1979-80

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer	Total Total P In	Total P Out	Source-/Sink +	%
October	53	0	53	41	12	22.6
November	15	0	15	2	13	86.7
December	76	0	76	3	73	96.1
January	182	0	182	2	180	98.9
February	106	0	106	3	103	97.2
March	121	0	121	1	120	99.2
April	136	0	136	1	135	99.3
May	205	0	205	0	205	100.0
June	197	0	197	0	197	100.0
July	394	0	394	1	393	99.7
August	212	0	212	0	212	100.0
September	136	0	136	0	136	100.0
ANNUAL TOTALS	1,834	0	1,834	54	1,780	97.1

LYKES NUTRIENT BUDGET

EAST WATERSHED

1980-81

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer	Total Total P In	Total P Out	Source-/Sink +	%
October	30	0	30	0	30	100.0
November	205	0	205	0	205	100.0
December	45	0	45	0	45	100.0
January	8	0	8	0	8	100.0
February	152	0	152	0	152	100.0
March	45	0	45	0	45	100.0
April	8	0	8	0	8	100.0
May	144	0	144	0	144	100.0
June	364	0	364	0	364	100.0
July	561	0	561	1	560	99.8
August	387	0	387	14	373	96.4
September	212	0	212	25	187	88.2
ANNUAL TOTALS	2,160	0	2,160	40	2,120	98.1

LYKES NUTRIENT BUDGET

EAST WATERSHED

1981-82

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer	Total Total P In	Total P Out	Source-/Sink +	%
October	45	0	45	2	43	95.6
November	68	0	68	0	68	100.0
December	0	0	0	0	0	-
January	159	0	159	0	159	100.0
February	174	0	174	0	174	100.0
March	432	0	432	0	432	100.0
April	280	0	280	0	280	100.0
May	227	0	227	1	226	99.6
June	508	0	508	36	472	92.9
July	258	0	258	14	244	94.6
August	227	0	227	24	203	89.4
September	174	0	174	16	158	90.8
ANNUAL TOTALS	2,554	0	2,554	93	2,461	96.4

ARMSTRONG SLOUGH WATER BUDGET

NORTH WATERSHED

1979-80

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake+/Discharge-	Percent Net Uptake+/Discharge-
October	91,080	3,877,274	-3,786,194	-41.6
November	555,588	168,343	387,245	69.7
December	2,128,236	131,885	1,996,351	93.8
January	1,387,452	111,576	1,275,876	92.0
February	2,222,352	313,442	1,908,910	85.9
March	1,387,452	275,270	1,112,182	80.2
April	1,572,648	136,535	1,436,113	91.3
May	3,424,608	216,546	3,208,062	93.7
June	3,330,492	92,980	3,237,512	97.2
July	6,569,904	105,948	6,463,956	98.4
August	3,239,412	667,225	2,572,157	79.4
September	2,128,236	181,311	1,946,925	91.5
ANNUAL TOTALS	28,037,460	6,278,365	21,759,095	77.6

ARMSTRONG SLOUGH WATER BUDGET

NORTH WATERSHED

1980-81

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake+/Discharge-	Percent Net Uptake+/Discharge-
October	555,588	116,715	438,872	79.0
November	2,498,628	128,459	2,370,169	94.9
December	831,864	130,173	701,691	84.4
January	185,196	95,672	89,524	48.3
February	1,757,844	184,247	1,573,597	89.5
March	1,017,060	119,651	897,409	88.2
April	0	152,684	-152,684	-
May	2,128,236	119,895	2,008,341	94.4
June	3,424,608	140,694	3,283,914	95.9
July	3,515,688	46,490	3,469,198	98.7
August	8,698,140	1,057,772	7,640,368	87.8
September	4,535,784	4,951,195	-415,411	-9.2
ANNUAL TOTALS	29,148,636	7,243,647	21,904,989	75.1

ARMSTRONG SLOUGH WATER BUDGET

NORTH WATERSHED

1981-82

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake+/Discharge-	Percent Net Uptake+/Discharge-
October	1,757,844	309,526	1,448,318	82.4
November	1,111,176	276,004	835,172	75.2
December	0	94,693	-94,693	-
January	1,111,176	98,363	1,012,813	91.1
February	2,128,236	211,408	1,916,828	90.1
March	3,515,688	271,110	3,244,578	92.3
April	2,589,708	1,100,592	1,489,116	57.5
May	3,700,884	752,650	2,948,234	79.7
June	9,624,120	3,794,815	5,829,305	60.6
July	3,700,884	2,048,010	1,652,874	44.7
August	7,866,276	2,343,835	5,522,441	70.2
September	5,643,924	4,613,043	1,030,884	18.3
ANNUAL TOTALS	43,749,916	15,914,046	26,835,870	62.8

ARMSTRONG SLOUGH NUTRIENT BUDGET

NORTH WATERSHED

1979-80

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer On Citrus	Inorganic N In Fertilizer On Pasture	Total Inorganic N In	Inorganic N Out	Source-/Sink+	%
October	61	77,000	0	77,061	430	76,631	99.4
November	372	0	0	372	12	360	96.8
December	1,426	0	0	1,426	3	1,423	99.8
January	930	77,000	0	77,930	3	77,927	100.0
February	1,489	0	0	1,489	6	1,483	99.6
March	930	0	0	930	6	924	99.4
April	1,054	0	82,100	83,154	3	93,151	100.0
May	2,295	77,000	82,100	161,395	5	161,390	100.0
June	2,231	0	82,100	84,331	3	84,328	100.0
July	4,402	0	0	4,402	9	4,393	99.8
August	2,171	77,000	0	79,171	105	79,066	99.9
September	1,426	0	0	1,426	20	1,406	98.6
ANNUAL TOTALS	18,785	308,000	246,300	573,085	605	572,480	99.9

ARMSTRONG SLOUGH NUTRIENT BUDGET

NORTH WATERSHED

1980-81

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer On Citrus	Inorganic N In Fertilizer On Pasture	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	372	77,000	0	77,372	8	77,364	100.0
November	1,674	0	0	1,674	9	1,665	99.5
December	557	0	0	557	10	547	98.2
January	124	77,000	0	77,124	8	77,116	100.0
February	1,178	0	0	1,178	6	1,172	99.5
March	681	0	0	681	2	679	99.7
April	0	0	82,100	82,100	3	82,097	100.0
May	1,426	77,000	82,100	160,526	3	160,523	100.0
June	2,295	0	82,100	84,395	5	84,390	100.0
July	2,355	0	0	2,355	21	2,334	99.1
August	5,828	77,000	0	82,828	277	82,551	99.7
September	3,039	0	0	3,039	1,231	1,808	59.5
ANNUAL TOTALS	19,530	308,000	246,300	573,830	1,583	572,247	99.7

ARMSTRONG SLOUGH NUTRIENT BUDGET

NORTH WATERSHED

1981-82

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer On Citrus	Inorganic N In Fertilizer On Pasture	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	1,178	77,000	0	78,178	68	78,110	99.9
November	744	0	0	744	45	699	94.0
December	0	0	0	0	5	-5	-
January	744	0	0	744	8	736	98.9
February	1,426	77,000	0	78,426	14	78,412	100.0
March	2,355	0	0	2,355	20	2,335	99.2
April	1,735	0	82,100	83,835	35	83,800	100.0
May	2,479	77,000	82,100	161,579	19	161,560	100.0
June	6,448	0	82,100	88,548	270	88,278	95.8
July	2,479	0	0	2,479	134	2,345	94.6
August	5,270	77,000	0	82,270	220	82,050	99.7
September	3,782	0	0	3,782	401	3,381	89.4
ANNUAL TOTALS	28,643	308,000	246,300	582,943	1,239	581,704	99.8

ARMSTRONG SLOUGH NUTRIENT BUDGET

NORTH WATERSHED

1979-80

Total N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer On Citrus	Total N In Fertilizer On Pasture	Total Total N In	Total N Out	Source-/Sink +	%
October	140	77,000	0	77,140	6,243	70,897	91.9
November	856	0	0	856	169	687	80.3
December	3,277	0	0	3,277	112	3,165	96.6
January	2,137	77,000	0	79,137	155	78,982	99.8
February	3,422	0	0	3,422	570	2,852	83.3
March	2,137	0	0	2,137	374	1,763	82.5
April	2,422	0	82,100	84,522	150	84,372	99.8
May	5,274	77,000	82,100	164,374	174	164,200	99.9
June	5,129	0	82,100	87,229	101	87,128	99.9
July	10,118	0	0	10,118	120	9,998	98.8
August	4,989	77,000	0	81,989	1,261	80,728	93.5
September	3,277	0	0	3,277	178	3,099	94.6
ANNUAL TOTALS	43,178	308,000	246,300	597,478	9,607	587,871	98.4

ARMSTRONG SLOUGH NUTRIENT BUDGET

NORTH WATERSHED

1980-81

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer On Citrus	Total N In Fertilizer On Pasture	Total Total N In	Total N Out	Source- /Sink +	%
October	856	77,000	0	77,856	88	77,768	99.9
November	3,848	0	0	3,848	87	3,761	97.7
December	1,281	0	0	1,281	97	1,184	92.4
January	285	77,000	0	77,285	74	77,211	99.9
February	2,707	0	0	2,707	147	2,560	94.6
March	1,566	0	0	1,566	97	1,469	93.8
April	0	0	82,100	82,100	137	81,963	99.8
May	3,277	77,000	82,100	162,377	134	162,243	99.9
June	5,274	0	82,100	87,374	113	87,261	99.9
July	5,414	0	0	5,414	79	5,335	98.5
August	13,395	77,000	0	90,395	3,552	86,843	96.1
September	6,984	0	0	6,985	15,723	-8,738	-125.1
ANNUAL TOTALS	44,889	308,000	246,300	599,189	20,328	578,861	96.6

ARMSTRONG SLOUGH NUTRIENT BUDGET

NORTH WATERSHED

1981-82

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer On Citrus	Total N In Fertilizer On Pasture	Total Total N In	Total N Out	Source- /Sink +	%
October	2,707	77,000	0	79,707	722	78,985	99.1
November	1,711	0	0	1,711	688	1,043	61.0
December	0	0	0	0	94	-94	-
January	1,711	77,000	0	78,711	94	78,617	99.9
February	3,277	0	0	3,277	369	2,908	88.7
March	5,414	0	0	5,414	487	4,927	91.0
April	3,988	0	82,100	86,088	2,057	84,031	97.6
May	5,699	77,000	82,100	164,799	1,096	163,703	99.3
June	14,821	0	82,100	96,921	6,127	90,794	93.7
July	5,699	0	0	5,699	3,164	2,535	41.0
August	12,114	77,000	0	89,114	4,553	84,561	94.9
September	8,692	0	0	8,692	6,757	1,935	22.3
ANNUAL TOTALS	65,835	308,000	246,300	620,135	26,188	593,947	95.8

ARMSTRONG SLOUGH NUTRIENT BUDGET

NORTH WATERSHED

1979-80

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer On Pasture	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	5.5	0	5.5	296	-290.5	-5,281.8
November	33.3	0	33.3	5	28.3	85.0
December	127.7	0	127.7	2	125.7	98.4
January	83.2	0	83.2	2	81.2	97.6
February	133.3	0	133.3	6	127.3	95.5
March	83.2	0	83.2	9	74.2	89.2
April	94.4	20,500	20,594.4	4	20,590.4	100.0
May	205.5	20,500	20,705.5	5	20,700.5	100.0
June	199.8	20,500	20,699.8	2	20,697.8	100.0
July	394.2	0	394.2	3	391.2	99.2
August	194.4	0	194.4	40	154.4	79.4
September	127.7	0	127.7	9	118.7	93.0
ANNUAL TOTALS	1,682.2	61,500	63,182.2	383	62,799.2	99.4

ARMSTRONG SLOUGH NUTRIENT BUDGET

NORTH WATERSHED

1980-81

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer On Pasture	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	33.3	0	33.3	3	30.3	91.0
November	149.9	0	149.9	3	146.9	98.0
December	49.9	0	49.9	3	46.9	94.0
January	11.1	0	11.1	3	8.1	73.0
February	105.5	0	105.5	6	99.5	94.3
March	61.0	0	61.0	3	58.0	95.1
April	0	20,500	20,500.0	4	20,496.0	100.0
May	127.7	20,500	20,627.7	3	20,624.7	100.0
June	205.5	20,500	20,705.5	4	20,701.5	100.0
July	210.9	0	210.9	2	208.9	99.1
August	521.9	0	521.9	479	42.9	8.2
September	272.1	0	272.1	1,639	-1,366.9	-502.4
ANNUAL TOTALS	1,748.9	61,500	63,429	2,152	61,096.9	96.6

ARMSTRONG SLOUGH NUTRIENT BUDGET

NORTH WATERSHED

1981-82

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer On Pasture	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	105.5	0	105.5	30	75.5	71.6
November	66.7	0	66.7	17	49.7	74.5
December	0	0	0	2	-2.0	-
January	66.7	0	66.7	2	64.7	97.0
February	127.7	0	127.7	11	116.7	91.4
March	210.9	0	210.9	10	200.0	95.3
April	155.4	20,500	20,655.4	26	20,629.4	99.9
May	222.1	20,500	20,722.1	22	20,700.1	99.9
June	577.4	20,500	21,077.4	125	20,952.4	99.4
July	222.1	0	222.1	37	185.1	83.3
August	472.0	0	472.0	35	437.0	92.6
September	338.6	0	338.6	67	271.6	80.2
ANNUAL TOTALS	2,565.0	61,500	64,065.0	384	63,681.0	99.4

ARMSTRONG SLOUGH NUTRIENT BUDGET

NORTH WATERSHED

1979-80

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer On Pasture	Total Total P In	Total P Out	Source-/Sink +	%
October	8.7	0	8.7	637	-628.3	-7,221.8
November	53.3	0	53.3	14	39.3	73.7
December	204.3	0	204.3	7	197.3	96.6
January	133.2	0	133.2	16	117.2	88.0
February	213.3	0	213.3	33	180.3	84.5
March	133.2	0	133.2	23	110.2	82.7
April	151.0	20,500	20,651.0	9	20,642.0	100.0
May	328.8	20,500	20,828.8	11	20,817.8	99.9
June	319.7	20,500	20,819.7	6	20,813.7	100.0
July	630.7	0	630.7	7	623.7	98.9
August	311.0	0	311.0	77	234.0	75.2
September	204.3	0	204.3	18	186.3	91.2
ANNUAL TOTALS	2,691.6	61,500	64,191.6	858	63,333.6	98.7

ARMSTRONG SLOUGH NUTRIENT BUDGET

NORTH WATERSHED

1980-81

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer On Pasture	Total Total P In	Total P Out	Source-/Sink +	%
October	53.3	0	53.3	10	43.3	81.2
November	239.9	0	239.9	7	232.9	97.1
December	79.9	0	79.9	6	73.9	92.5
January	17.8	0	17.8	7	10.8	60.7
February	168.8	0	168.8	12	156.8	92.9
March	97.6	0	97.6	6	91.6	93.9
April	0	20,500	2,500.0	7	20,493.0	100.0
May	204.3	20,500	20,704.3	7	20,697.3	100.0
June	328.8	20,500	20,828.8	10	20,818.8	100.0
July	337.5	0	337.5	5	332.5	98.5
August	835.0	0	835.0	654	181.0	21.7
September	435.4	0	435.4	2,353	-1,917.6	-440.4
ANNUAL TOTALS	2,798.3	61,500	64,298.3	3,084	61,214.3	95.2

ARMSTRONG SLOUGH NUTRIENT BUDGET

NORTH WATERSHED

1981-82

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer On Pasture	Total Total P In	Total P Out	Source-/Sink +	%
October	168.8	0	168.8	51	117.8	69.8
November	106.7	0	106.7	42	64.7	60.6
December	0	0	0	5	-5.0	-
January	106.7	0	106.7	6	100.7	94.4
February	204.3	0	204.3	23	181.3	88.7
March	337.5	0	337.5	26	311.5	92.3
April	248.6	20,500	20,748.6	94	20,654.6	99.5
May	355.3	20,500	20,855.3	52	20,803.3	99.8
June	923.9	20,500	21,423.9	30	21,393.9	99.9
July	355.3	0	355.3	133	222.3	62.6
August	755.2	0	755.2	133	622.2	82.4
September	541.8	0	541.8	286	255.8	47.2
ANNUAL TOTALS	4,104.0	61,500	65,604.0	881	64,723.0	98.7

ARMSTRONG SLOUGH WATER BUDGET

SOUTH WATERSHED

1979-80

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake+/Discharge-	Percent Net Uptake+/Discharge-
October	30,360	437,007	-406,647	-1,339.4
November	185,196	27,649	157,547	85.1
December	709,412	29,851	679,561	95.8
January	462,484	17,862	444,622	96.1
February	740,784	105,948	634,836	85.7
March	462,484	101,544	360,940	78.0
April	524,216	57,501	466,715	89.0
May	1,141,536	1,958	1,139,578	99.8
June	1,110,164	12,234	1,097,930	98.9
July	2,189,968	17,617	2,172,351	99.2
August	1,079,804	154,396	925,408	85.7
September	709,412	96,161	613,251	86.4
ANNUAL TOTALS	9,345,820	1,059,728	8,286,092	88.7

ARMSTRONG SLOUGH WATER BUDGET

SOUTH WATERSHED

1980-81

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake+/Discharge-	Percent Net Uptake+/Discharge-
October	185,196	6,852	178,344	96.3
November	832,876	3,182	829,694	99.6
December	277,288	3,182	274,106	98.9
January	61,732	14,926	46,806	75.8
February	585,948	84,905	501,043	85.5
March	339,020	35,724	303,296	89.5
April	0	244	-244	-
May	709,412	0	709,412	100.0
June	1,141,536	0	1,141,536	100.0
July	1,171,896	0	1,171,896	100.0
August	2,899,380	33,522	2,865,858	98.8
September	1,511,928	1,741,666	-229,738	-15.2
ANNUAL TOTALS	9,716,212	1,924,203	7,792,009	80.2

ARMSTRONG SLOUGH WATER BUDGET

SOUTH WATERSHED

1981-82

Month	Estimated Rainfall On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake +/Discharge-	Percent Net Uptake +/Discharge-
October	585,948	56,522	529,426	90.4
November	370,392	93,714	276,678	74.7
December	0	0	0	-
January	370,392	0	370,392	100.0
February	709,412	23,979	685,433	96.6
March	1,171,896	166,630	1,005,266	85.8
April	863,236	919,035	-55,799	-6.5
May	1,233,628	212,142	1,021,486	82.8
June	3,208,040	2,613,477	594,563	18.5
July	1,233,628	995,622	238,006	19.3
August	2,622,092	1,276,275	1,345,817	51.3
September	1,881,308	3,372,978	-1,491,670	-79.3
ANNUAL TOTALS	14,249,972	9,730,374	4,519,598	31.7

ARMSTRONG SLOUGH NUTRIENT BUDGET

SOUTH WATERSHED

1979-80

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	20.4	0	20.4	11	9.4	46.1
November	124.1	0	124.1	1	123.1	99.2
December	475.3	0	475.3	1	474.3	99.8
January	309.9	0	309.9	0	309.9	100.0
February	496.3	0	496.3	10	486.3	98.0
March	309.9	0	309.9	16	293.9	94.8
April	351.2	14,145	14,496.2	12	14,484.2	99.9
May	764.8	14,145	14,909.8	0	14,909.8	100.0
June	743.8	14,145	14,888.8	0	14,888.8	100.0
July	1,467.3	0	1,467.3	0	1,467.3	100.0
August	723.5	0	723.5	2	721.5	99.7
September	475.3	0	475.3	2	473.3	99.6
ANNUAL TOTALS	6,261.7	42,435	48,696.7	55	48,641.7	99.9

ARMSTRONG SLOUGH NUTRIENT BUDGET

SOUTH WATERSHED

1980-81

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	124.1	0	124.1	0	124.1	100.0
November	558.0	0	558.0	0	558.0	100.0
December	185.8	0	185.8	0	185.8	100.0
January	41.4	0	41.4	0	41.4	100.0
February	392.6	0	392.6	1	391.6	99.7
March	227.1	0	227.1	0	227.1	100.0
April	0	14,145	14,145.0	0	14,145.0	100.0
May	475.3	14,145	14,620.3	0	14,620.3	100.0
June	764.8	14,145	14,909.9	0	14,909.8	100.0
July	785.2	0	785.2	0	785.2	100.0
August	1,942.6	0	1,942.6	2	1,940.6	99.9
September	1,013.0	0	1,013.0	104	909.0	89.7
ANNUAL TOTALS	6,509.0	42,435	48,944.9	107	48,837.9	99.8

ARMSTRONG SLOUGH NUTRIENT BUDGET

SOUTH WATERSHED

1981-82

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Fertilizer	Total InorganicN In	Inorganic N Out	Source-/Sink +	%
October	392.6	0	392.6	3	389.6	99.2
November	248.2	0	248.2	3	245.2	98.8
December	0	0	0	0	0	-
January	248.2	0	248.2	0	248.2	100.0
February	475.3	0	475.3	2	473.3	99.6
March	785.2	0	785.2	4	781.2	99.5
April	578.4	14,145	14,723.4	23	14,700.4	99.8
May	826.5	14,145	14,971.5	3	14,968.5	100.0
June	2,149.4	14,145	16,294.4	51	16,243.4	99.7
July	826.5	0	826.5	16	810.5	98.1
August	1,756.8	0	1,756.8	16	1,740.8	99.1
September	1,260.5	0	1,260.5	50	1,210.5	96.0
ANNUAL TOTALS	9,547.5	42,435	51,982.5	171	51,811.5	99.7

ARMSTRONG SLOUGH WATER BUDGET

SOUTH WATERSHED

1979-80

Total N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer	Total Total N In	Total N Out	Source-/Sink +	%
October	46.8	0	46.8	621	-574.2	-1,226.9
November	285.2	0	285.2	37	248.2	87.0
December	1,092.5	0	1,092.5	40	1,052.5	96.3
January	712.2	0	712.2	22	690.2	96.9
February	1,140.8	0	1,140.8	134	1,006.8	88.3
March	712.2	0	712.2	180	532.2	74.7
April	807.3	14,145	14,952.3	138	14,814.3	99.1
May	1,758.0	14,145	15,903.0	3	15,900.0	100.0
June	1,709.7	14,145	15,854.7	26	15,828.7	99.8
July	3,372.6	0	3,372.6	25	3,347.6	99.3
August	1,662.9	0	1,662.9	204	1,458.9	87.7
September	1,092.5	0	1,092.5	91	1,001.5	91.7
ANNUAL TOTALS	14,392.6	42,435	56,827.6	1,521	55,306.6	97.3

ARMSTRONG SLOUGH NUTRIENT BUDGET

SOUTH WATERSHED

1980-81

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer	Total Total N In	Total N Out	Source-/Sink +	%
October	285.2	0	285.2	8	277.2	97.2
November	1,282.6	0	1,282.6	5	1,277.6	99.6
December	427.0	0	427.0	3	424.0	99.3
January	95.1	0	95.1	14	81.1	85.3
February	902.4	0	902.4	100	802.4	88.9
March	522.1	0	522.1	50	472.1	90.4
April	0	14,145	14,145.0	0	14,145.0	100.0
May	1,092.5	14,145	15,237.5	0	15,237.5	100.0
June	1,758.0	14,145	15,903.0	0	15,903.0	100.0
July	1,804.7	0	1,804.7	0	1,804.7	100.0
August	4,465.0	0	4,465.0	80	4,385.0	98.2
September	2,328.4	0	2,328.4	4,370	-2,042.4	-87.7
ANNUAL TOTALS	14,963.0	42,435	57,398.0	4,630	52,768.0	91.9

ARMSTRONG SLOUGH NUTRIENT BUDGET

SOUTH WATERSHED

1981-82

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Fertilizer	Total Total N In	Total N Out	Source-/Sink +	%
October	902.4	0	902.4	144	758.4	84.0
November	570.4	0	570.4	199	371.4	65.1
December	0	0	0	0	0	-
January	570.4	0	570.4	0	570.4	100.0
February	1,092.5	0	1,092.5	59	1,033.5	94.6
March	1,804.7	0	1,804.7	336	1,468.7	81.4
April	1,329.4	14,145	15,474.4	1,609	13,865.4	89.6
May	1,899.8	14,145	16,044.8	368	15,676.8	97.7
June	4,940.4	14,145	19,085.4	3,702	15,383.4	80.1
July	1,899.8	0	1,899.8	1,237	662.8	34.9
August	4,038.0	0	4,038.0	1,674	2,364.0	58.5
September	2,897.2	0	2,897.2	3,703	-806.2	-27.8
ANNUAL TOTALS	21,945.0	42,435	64,380.0	13,031	51,349.0	79.8

ARMSTRONG SLOUGH NUTRIENT BUDGET

SOUTH WATERSHED

1979-80

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	1.8	0	1.8	6	-4.2	-233.3
November	11.1	0	11.1	0	11.1	100.0
December	42.6	0	42.6	1	41.6	97.7
January	27.7	0	27.7	0	27.7	100.0
February	44.4	0	44.4	2	42.4	95.5
March	27.7	0	27.7	1	26.7	96.4
April	31.5	3,536	3,567.5	1	3,566.5	100.0
May	68.5	3,536	3,604.5	0	3,604.5	100.0
June	66.6	3,536	3,602.6	0	3,602.6	100.0
July	131.4	0	131.4	0	131.4	100.0
August	64.8	0	64.8	2	62.8	96.9
September	42.6	0	42.6	1	41.6	97.7
ANNUAL TOTALS	560.7	10,608	11,168.7	14	11,154.7	99.9

ARMSTRONG SLOUGH NUTRIENT BUDGET

SOUTH WATERSHED

1980-81

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	11.1	0	11.1	0	11.1	100.0
November	50.0	0	50.0	0	50.0	100.0
December	16.6	0	16.6	0	16.6	100.0
January	3.7	0	3.7	0	3.7	100.0
February	35.2	0	36.2	1	34.2	97.2
March	20.3	0	20.3	0	20.3	100.0
April	0	3,536	3,536.0	0	3,536.0	100.0
May	42.6	3,536	3,578.6	0	3,578.6	100.0
June	68.5	3,536	3,604.5	0	3,604.5	100.0
July	70.3	0	70.3	0	70.3	100.0
August	174.0	0	174.0	4	170.0	97.7
September	90.7	0	90.7	101	-10.4	-11.4
ANNUAL TOTALS	583.0	10,608	11,191.0	106	11,085.0	99.3

ARMSTRONG SLOUGH NUTRIENT BUDGET

SOUTH WATERSHED

1981-82

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Fertilizer	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	35.2	0	35.2	2	33.2	94.3
November	22.2	0	22.2	1	21.2	95.5
December	0	0	0	0	0	-
January	22.2	0	22.2	0	22.2	100.0
February	42.6	0	42.6	2	40.6	95.3
March	70.3	0	70.3	3	67.3	95.7
April	51.8	3,536	3,587.8	17	3,570.8	99.5
May	74.0	3,536	3,610.0	4	3,606.0	99.9
June	192.5	3,536	3,720.5	42	3,686.5	98.9
July	74.0	0	74.0	9	65.0	87.8
August	157.3	0	157.3	5	152.3	96.8
September	112.9	0	112.9	23	89.9	79.6
ANNUAL TOTALS	855.0	10,608	11,463.0	107	11,356.0	99.1

ARMSTRONG SLOUGH NUTRIENT BUDGET

SOUTH WATERSHED

1979-80

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer	Total Total P In	Total P Out	Source-/Sink +	%
October	2.9	0	2.9	19	-16.1	-555.2
November	17.8	0	17.8	1	16.8	94.4
December	68.2	0	68.2	2	66.2	97.1
January	44.3	0	44.3	1	43.3	97.7
February	71.0	0	71.0	10	61.0	85.9
March	44.3	0	44.3	8	36.3	81.9
April	50.4	3,536	3,586.4	9	3,577.4	99.7
May	109.6	3,536	3,645.6	0	3,645.6	100.0
June	106.6	3,536	3,642.6	1	3,641.6	100.0
July	210.2	0	210.2	1	209.2	99.5
August	103.7	0	103.7	4	99.7	96.1
September	68.2	0	68.2	3	65.2	95.6
ANNUAL TOTALS	897.1	10,608	11,505.1	59	11,446.1	99.5

ARMSTRONG SLOUGH NUTRIENT BUDGET

SOUTH WATERSHED

1980-81

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer	Total Total P In	Total P Out	Source-/Sink +	%
October	17.8	0	17.8	0	17.8	100.0
November	80.0	0	80.0	0	80.0	100.0
December	26.6	0	26.6	0	26.6	100.0
January	5.9	0	5.9	0	5.9	100.0
February	56.3	0	56.3	3	53.3	94.7
March	32.5	0	32.5	2	30.5	93.8
April	0	3,536	3,536.0	0	3,536.0	100.0
May	68.2	3,536	3,604.2	0	3,604.2	100.0
June	109.6	3,536	3,645.6	0	3,645.6	100.0
July	112.5	0	112.5	0	112.5	100.0
August	278.4	0	278.4	7	271.4	97.5
September	145.1	0	145.1	236	-90.9	-62.6
ANNUAL TOTALS	932.8	10,608	11,540.8	248	11,292.8	97.9

ARMSTRONG SLOUGH NUTRIENT BUDGET

SOUTH WATERSHED

1981-82

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Fertilizer	Total Total P In	Total P Out	Source-/Sink +	%
October	56.3	0	56.3	6	50.3	89.3
November	35.5	0	35.5	5	30.5	85.9
December	0	0	0	0	0	-
January	35.5	0	35.5	0	35.5	100.0
February	68.2	0	68.2	5	63.2	92.7
March	112.5	0	112.5	12	100.5	89.3
April	82.9	3,536	3,618.9	66	3,552.9	98.2
May	118.4	3,536	3,654.4	15	3,639.4	99.6
June	308.0	3,536	3,844.0	153	3,691.0	96.0
July	118.4	0	118.4	40	78.4	66.2
August	261.7	0	261.7	43	218.7	83.6
September	180.6	0	180.6	89	91.6	50.7
ANNUAL TOTALS	1,368.0	10,608	11,976.0	434	11,542.0	96.4

SEZ DAIRY WATER BUDGET

DISCHARGE AT WOLF CREEK

1979-80

Month	Estimated Rainfall on Watershed (m^3)	Lagoon Discharge (m^3)	Total On Watershed (m^3)	Measured Discharge at Monitoring Station (m^3)	Net Uptake + /Discharge-	Percent Net Uptake +/ Discharge-
October	30,030		30,030*	34,868*	75,682*	68.5*
November	80,520		80,520*			
December	201,300		201,300*	34,990	166,310*	82.6*
January	170,940		170,940*	25,203	145,737*	85.3
February	120,780		120,780*	36,947	83,833*	69.4*
March	110,550		110,550*	28,383	82,167*	74.3
April	150,810		150,810*	23,735	127,075*	84.3*
May	110,550	2,271	112,821	4,894	107,927	95.7
June	352,110	2,958	355,068	5,872	349,196	98.3
July	764,280	5,875	770,155	57,012	713,143	92.6
August	432,630	4,011	436,641	81,726	354,916	81.3
September	372,240	12,341	384,581	175,194	209,387	54.4
ANNUAL TOTALS	2,896,740	27,456	2,924,196*	508,823*	2,415,373*	82.6*

*Estimated Value

SEZ DAIRY WATER BUDGET

DISCHARGE AT WOLF CREEK

1980-81

Month	Estimated Rainfall On Watershed (m^3)	Lagoon Discharge (m^3)	Total On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake +/ Discharge	Percent Net Uptake +/ Discharge
October	30,030	4,675	34,705	11,500	23,205	66.9
November	331,980	2,453	334,433	20,064	314,369	94.0
December	60,390	4,597	64,987	15,171	49,816	76.7
January	20,130	3,260	23,390	2,936	20,454	87.4
February	150,810	9,788	160,598	24,957	135,641	84.5
March	0	1,929	1,929	978	951	49.3
April	0	3,305	3,305	0	3,305	100.0
May	291,720	2,459	289,261	0	289,261	100.0
June	512,820	1,925	514,745	0	514,745	100.0
July	553,080	4,743	557,823	14,436	543,387	97.4
August	643,830	4,569	648,398	124,545	523,853	80.8
September	583,440	6,218	589,658	396,389	193,269	32.8
ANNUAL TOTALS	3,178,230	49,921	3,228,151	610,976	2,617,175	81.1

SEZ DAIRY WATER BUDGET

DISCHARGE AT WOLF CREEK

1981-82

Month	Estimated Rainfall On Watershed (m^3)	Lagoon Discharge (m^3)	Total On Watershed (m^3)	Measured Discharge At Monitoring Station (m^3)	Net Uptake+/ Discharge-	Percent Net Uptake+/ Discharge-
October	9,900	4,669	14,569	31,075	-16,506	-113.3
November	9,900	2,400	12,300	7,096	5,204	42.3
December	0	4,917	4,917	0	4,917	100.0
January	20,130	2,553	22,683	0	22,683	100.0
February	0	2,580	2,580	0	2,580	100.0
March	432,630	5,986	438,616	46,490	392,126	89.4
April	352,110	4,384	356,494	99,832	256,662	72.0
May	543,180	3,377	546,557	154,152	392,405	71.8
June	764,280	9,659	773,939	454,135	319,804	41.3
July	593,340	4,590	597,930	282,611	315,319	52.7
August	673,860	8,482	682,342	304,143	378,199	55.4
September	724,350	7,526	731,876	483,497	248,379	33.9
ANNUAL TOTALS	4,123,680	61,123	4,184,803	1,863,031	2,321,772	55.5

SEZ DAIRY NUTRIENT BUDGET

DISCHARGE AT WOLF CREEK

1979-80

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads + Lagoon Discharge = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Lagoon Discharge	Inorganic N In Fertilizer	Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	20.1				85*		
November	53.9						
December	134.9				42		
January	114.5				81		
February	80				19		
March	74.0				5		
April	101.0		32,647	32,748	35	32,713	99.9
May	74.0	46.4	32,647	32,767	0	32,767	100.0
June	235.9	60.4		296	0	296	100.0
July	512.1	120.1		632	44	588	93.0
August	289.9	82.0		372	110	262	70.4
September	249.4	252.2		501	449	52	10.4
ANNUAL TOTALS	1,940.8	561.1	65,294	61,317	723*	66,679	99.1

*Estimated Value

SEZ DAIRY NUTRIENT BUDGET

DISCHARGE AT WOLF CREEK

1980-81

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads + Lagoon Discharge = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Lagoon Discharge	Inorganic N In Fertilizer	Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	20.1	95.6		116	21	95	81.9
November	222.4	50.1		272	14	258	94.9
December	40.5	94.0		135	2	133	98.5
January	13.5	66.6		81	0	81	100.0
February	101.0	200.0		301	11	290	96.3
March	0	39.4		39	0	39	100.0
April	0	67.5	32,647	32,715	0	32,715	100.0
May	195.4	50.3	32,647	32,892	0	32,892	100.0
June	343.6	39.3		383	0	383	100.0
July	370.5	97.0		468	7	461	98.5
August	431.4	93.4		524	96	428	81.7
September	390.9	127.1		518	177	341	65.8
ANNUAL TOTALS	2,129.4	1,020.3	65,294	68,443	328	68,115	99.5

SEZ DAIRY NUTRIENT BUDGET

DISCHARGE AT WOLF CREEK

1981-82

INORGANIC N (Kilograms)

Rainfall Loads + Fertilizer Loads = Total Loads - Loads Out = Source/Sink

Month	Inorganic N In Rainfall	Inorganic N In Lagoon Discharge	Inorganic N In Fertilizer	Inorganic N In	Inorganic N Out	Source- /Sink +	%
October	6.6	95.4		102	132	-30	-29.4
November	6.6	49.0		55	3	52	94.5
December	0	100.5		101	0	101	100.0
January	13.5	52.2		66	0	66	100.0
February	0	52.7		53	0	53	100.0
March	289.9	122.3		412	155	257	62.4
April	235.9	89.6	32,647	32,973	38	32,935	99.9
May	363.9	69.1	32,647	33,081	57	33,024	99.8
June	512.1	197.4		709	410	299	42.2
July	397.5	93.8		492	284	208	42.3
August	451.5	173.4		625	695	-70	-11.2
September	485.3	153.8		639	788	-149	-23.3
ANNUAL TOTALS	2,762.9	1,249.4	65,294	69,306	2,562	66,744	96.3

SEZ DAIRY NUTRIENT BUDGET

DISCHARGE AT WOLF CREEK

1979-80

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads + Lagoon Discharge = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Lagoon Discharge	Total N In Fertilizer	Total N In	Total N Out	Source-/Sink +	%
October	46.2				179*		
November	124.0						
December	310.0				113		
January	263.2				148		
February	186.0				88		
March	170.2				60		
April	232.2		32,647	32,879	116	32,763	99.6
May	170.2	92.8	32,647	32,910	9	32,901	100.0
June	542.2	120.8		663	15	648	97.7
July	1,177.0	240.0		1,417	252	1,165	82.2
August	666.3	163.8		830	415	415	50.0
September	573.2	504.1		1,077	1,203	-126	-11.7
ANNUAL TOTALS	4,461.0	1,121.5	65,294	69,776	2,189*	67,766	97.1

*Estimated Value

SEZ DAIRY NUTRIENT BUDGET

DISCHARGE AT WOLF CREEK

1980-81

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads + Lagoon Discharge = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Lagoon Discharge	Total N In Fertilizer	Total N In	Total N Out	Source-/Sink +	%
October	46.2	191.0		237	49	188	79.3
November	511.2	100.2		611	71	540	88.4
December	93.0	187.8		281	36	245	87.2
January	31.0	133.2		164	5	159	97.0
February	232.2	399.8		632	151	481	76.1
March	0	78.8		79	2	77	97.5
April	0	135.0	32,647	32,782	0	32,782	100.0
May	449.2	100.5	32,647	33,197	0	33,197	100.0
June	789.7	78.6		869	0	869	100.0
July	851.7	193.8		1,046	71	975	93.2
August	991.5	186.6		1,179	553	626	53.1
September	898.5	254.0		1,153	1,325	-172	-14.9
ANNUAL TOTALS	4,894.5	2,039.2	65,294	72,228	2,263	69,965	96.9

SEZ DAIRY NUTRIENT BUDGET

DISCHARGE AT WOLF CREEK

1981-82

TOTAL N (Kilograms)

Rainfall Loads + Fertilizer Loads + Lagoon Discharge = Total Loads - Loads Out = Source/Sink

Month	Total N In Rainfall	Total N In Lagoon Discharge	Total N In Fertilizer	Total N In	Total N Out	Source-/Sink +	%
October	15.2	190.7		206	220	-14	-6.8
November	15.2	98.0		113	17	96	85.0
December	0	200.9		201	0	201	100.0
January	31.0	104.3		135	0	135	100.0
February	0	105.4		105	0	105	100.0
March	666.3	244.5		911	392	519	57.0
April	542.2	179.1	32,647	33,368	286	33,082	99.1
May	836.5	138.0	32,647	33,622	688	32,934	98.0
June	1,177.0	394.6		1,572	1,683	-111	-7.1
July	913.7	187.5		1,102	985	117	10.6
August	1,037.7	346.5		1,385	1,670	-285	-20.6
September	1,115.5	307.4		1,423	2,010	-587	-41.2
ANNUAL TOTALS	6,350.5	2,496.9	65,294	74,142	7,951	66,191	89.3

SEZ DAIRY NUTRIENT BUDGET

DISCHARGE AT WOLF CREEK

1979-80

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads + Lagoon Discharge = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Lagoon Discharge	Ortho P In Fertilizer	Ortho P In Manure	Ortho P In	Ortho P Out	Source-/Sink +	%
October	1.8			650	652			
November	4.8			650	655	48*		
December	12.1			650	662	12	650	98.2
January	10.3			650	660	6	654	99.1
February	7.2			650	657	22	635	96.7
March	6.6			650	657	15	642	97.7
April	9.0		2,924	650	3,583	4	3,579	99.9
May	6.6	9.8	2,924	650	3,591	1	3,590	100.0
June	21.1	12.8		650	684	1	683	99.9
July	45.9	25.4		650	721	125	596	82.7
August	26.0	17.3		650	693	177	516	74.5
September	22.3	53.3		650	725	439	290	40.0
ANNUAL TOTALS	173.8	118.6	5,848	7,794	13,934	850*	13,084	93.9

*Estimated Value

SEZ DAIRY NUTRIENT BUDGET

DISCHARGES AT WOLF CREEK

1980-81

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads + Lagoon Discharge = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Lagoon Discharge	Ortho P In Fertilizer	Ortho P In Manure	Ortho P In	Ortho P Out	Source- /Sink +	%
October	1.8	20.2		650	672	11	661	98.4
November	19.9	10.6		650	681	40	641	94.1
December	3.6	19.9		650	674	8	666	98.0
January	1.2	14.1		650	665	1	664	99.8
February	9.0	42.3		650	701	103	598	85.3
March	0	8.3		650	658	5	653	99.2
April	0	14.3	2,924	650	3,588	0	3,588	100.0
May	17.5	10.6	2,924	650	3,603	0	3,603	100.0
June	30.8	8.3		650	689	0	689	100.0
July	33.2	20.5		650	704	37	667	94.7
August	38.6	19.7		650	709	235	474	66.9
September	35.0	26.9		650	712	730	-18	-2.5
ANNUAL TOTALS	190.7	215.7	5,848	7,794	14,049	1,170	9,879	70.3

SEZ DAIRY NUTRIENT BUDGET

DISCHARGES AT WOLF CREEK

1981-82

ORTHO P (Kilograms)

Rainfall Loads + Fertilizer Loads + Lagoon Discharge = Total Loads - Loads Out = Source/Sink

Month	Ortho P In Rainfall	Ortho P In Lagoon Discharge	Ortho P In Fertilizer	Ortho P In Manure	Ortho P In	Ortho P Out	Source-/Sink +	%
October	0.6	20.2		650	671	42	629	93.7
November	0.6	10.4		650	661	2	659	99.7
December	0	21.2		650	671	0	671	100.0
January	1.2	11.0		650	662	0	662	100.0
February	0	11.1		650	671	0	671	100.0
March	26.0	25.9		650	702	109	593	84.5
April	21.1	18.9	2,924	650	3,614	164	3,450	95.5
May	32.6	14.6	2,924	650	3,622	360	3,262	90.1
June	45.9	41.7		650	738	633	105	14.2
July	35.6	19.8		650	706	299	427	60.5
August	40.4	36.6		650	727	460	267	36.7
September	43.5	32.5		650	727	647	80	11.0
ANNUAL TOTALS	247.4	264.1	5,848	7,794	14,153	2,716	11,437	80.8

SEZ DAIRY NUTRIENT BUDGET

DISCHARGES AT WOLF CREEK

1979-80

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads + Lagoon Discharge = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Lagoon Discharge	Total P In Fertilizer	Total P In Manure	Total P In	Total P Out	Source-/Sink +	%
October	2.9			650	653	76*		
November	7.7			650	658			
December	19.3			650	669	41	628	93.9
January	16.4			650	666	16	650	97.6
February	11.6			650	662	33	629	95.0
March	10.6			650	661	23	638	96.5
April	14.5		2,924	650	3,589	17	3,572	99.5
May	10.6	23.7	2,924	650	3,609	2	3,607	99.9
June	33.8	30.9		650	715	2	713	99.7
July	73.4	61.3		650	784	186	598	76.3
August	41.5	41.8		650	734	242	492	67.0
September	35.7	128.8		650	815	606	209	25.6
ANNUAL TOTALS	278.1	286.5	5,848	7,794	14,215	1,244*	12,971	91.2

*Estimated Value

SEZ DAIRY NUTRIENT BUDGET

DISCHARGES AT WOLF CREEK

1980-81

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads + Lagoon Discharge = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Lagoon Discharge	Total P In Fertilizer	Total P In Manure	Total P In	Total P Out	Source-/Sink +	%
October	2.9	48.8		650	702	22	680	96.9
November	31.9	25.6		650	708	54	654	92.4
December	5.8	48.0		650	704	11	693	98.4
January	1.9	34.0		650	686	1	685	99.9
February	14.5	102.1		650	767	139	628	81.9
March	0	20.1		650	670	5	665	99.3
April	0	34.5	2,924	650	3,609	0	3,609	100.0
May	28.0	25.7	2,924	650	3,628	0	3,628	100.0
June	49.2	20.1		650	719	0	719	100.0
July	53.1	49.5		650	753	53	700	93.0
August	61.8	47.7		650	760	291	469	61.7
September	56.0	64.9		650	771	812	-41	-5.3
ANNUAL TOTALS	305.1	520.9	5,848	7,794	14,468	1,388	13,080	90.4

SEZ DAIRY NUTRIENT BUDGET

DISCHARGES AT WOLF CREEK

1981-82

TOTAL P (Kilograms)

Rainfall Loads + Fertilizer Loads + Lagoon Discharge = Total Loads - Loads Out = Source/Sink

Month	Total P In Rainfall	Total P In Lagoon Discharge	Total P In Fertilizer	Total P In Manure	Total P In	Total P Out	Source-/Sink +	%
October	0.9	48.7		650	700	72	628	89.7
November	0.9	25.0		650	676	3	673	99.6
December	0	51.3		650	701	0	701	100.0
January	1.9	26.6		650	679	0	679	100.0
February	0	26.9		650	677	0	677	100.0
March	41.5	62.5		650	755	137	618	81.9
April	33.8	45.8	2,924	650	3,654	216	3,438	94.1
May	52.1	35.3	2,924	650	3,661	431	3,230	88.2
June	73.4	100.8		650	824	714	110	13.3
July	57.0	47.9		650	755	346	409	54.2
August	64.7	88.5		650	804	513	291	36.2
September	69.5	78.5		650	799	757	42	5.3
ANNUAL TOTALS	395.9	637.8	5,848	7,794	14,676	3,189	11,487	78.3

APPENDIX II

Monthly And Annual Water And Nutrient Budgets For The Ash Slough And Armstrong Slough Detention/Retention Wetlands

ASH SLOUGH MARSH WATER BUDGET

(Cubic Meters)

1979-80

West Watershed Loads + East Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Flow In West Watershed	Flow In East Watershed	RainfalOn Marsh Surface	Runoff From Ungaged Area	Total Flow In	Total Flow Out	Net Uptake +/ Discharge	% Uptake Discharge
October	41,107	7,096	866	294	49,363	68,512	-19,149	-38.8
November	0	0	695	236	931	490	441	47.4
December	0	0	2,953	1,002	3,955	0	3,955	100.0
January	0	734	2,782	944	4,460	978	3,482	78.1
February	25,447	6,606	3,648	1,238	36,939	27,161	9,778	26.5
March	7,830	2,692	3,825	1,298	15,645	25,203	-9,558	-61.1
April	91,267	1,224	5,387	1,829	99,707	54,564	45,143	42.3
May	0	0	1,043	354	1,397	0	1,397	100.0
June	0	0	4,343	1,474	5,817	0	5,817	100.0
July	75,119	978	12,512	4,247	92,856	15,415	77,441	83.4
August	36,458	978	11,121	3,775	52,332	14,436	37,896	72.4
September	156,598	11,256	11,292	3,833	182,979	158,066	24,913	13.6
ANNUAL TOTALS	433,826	31,563	60,466	20,527	546,382	364,824	181,558	33.2

ASH SLOUGH MARSH WATER BUDGET

(Cubic Meters)

1980-81

West Watershed Loads + East Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Flow In West Watershed	Flow In East Watershed	RainfalOn Marsh Surface	Runoff From Ungaged Area	Total Flow In	Total Flow Out	Net Uptake +/ Discharge	% Uptake Discharge
October	0	0	695	236	931	0	931	100.0
November	0	0	5,558	1,887	7,445	0	7,445	100.0
December	0	0	1,214	412	1,626	0	1,626	100.0
January	0	0	0	0	0	0	0	-
February	0	0	3,996	1,356	5,352	0	5,352	100.0
March	0	0	1,043	354	1,397	0	1,397	100.0
April	0	0	0	0	0	0	0	-
May	0	0	2,086	708	2,794	0	2,794	100.0
June	0	0	3,300	1,120	4,420	0	4,420	100.0
July	0	0	7,296	2,477	9,773	0	9,773	100.0
August	0	0	9,901	3,361	13,262	0	13,262	100.0
September	2,936	244	6,253	2,123	11,556	0	11,556	100.0
ANNUAL TOTALS	2,936	244	41,342	14,035	58,557	0	58,557	100.0

ASH SLOUGH MARSH WATER BUDGET

(Cubic Meters)

1981-82

West Watershed Loads + East Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Flow In West Watershed	Flow In East Watershed	Rainfall On Marsh Surface	Runoff From Ungaged Area	Total Flow In	Total Flow Out	Net Uptake +/ Discharge	% Net Uptake Discharge
October	0	0	866	294	1,160	0	1,160	100.0
November	0	0	1,305	443	1,748	0	1,748	100.0
December	0	0	0	0	0	0	0	-
January	0	0	1,800	611	2,411	0	2,411	100.0
February	0	0	3,825	1,298	5,123	0	5,123	100.0
March	42,086	244	2,605	884	45,819	16,639	29,180	63.6
April	148,279	2,692	4,332	1,471	156,774	121,363	35,411	22.6
May	978	978	5,039	1,710	8,705	21,777	-13,072	-150.2
June	158,556	10,766	9,553	3,243	182,118	109,374	72,744	39.9
July	88,087	3,670	7,820	2,655	102,232	84,171	18,061	17.7
August	46,490	2,692	8,858	3,007	61,047	51,628	9,419	15.4
September	78,055	5,384	10,944	3,715	98,098	94,693	3,405	3.5
ANNUAL TOTALS	562,531	26,425	56,886	19,311	665,153	499,645	165,508	24.9

ASH SLOUGH MARSH NUTRIENT BUDGET

1979-80

INORGANIC N (Kilograms)

West Watershed Loads + East Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Inorganic N West Watershed	Inorganic N East Watershed	Inorganic N Rainfall	Inorganic N Ungaged Runoff	Total Inorganic N In	Inorganic N Out	Source- /Sink +	%
October	1	0	.6	.2	1.8	3	-1.2	-66.7
November	0	0	.5	.2	0.7	0	0.7	100.0
December	0	0	2.0	.7	2.7	0	2.7	100.0
January	0	0	1.9	.6	2.5	0	2.5	100.0
February	1	0	2.5	.9	4.4	1	3.4	77.3
March	1	0	2.6	.9	4.5	1	3.5	77.8
April	21	0	3.7	1.3	26.0	6	20.0	76.9
May	0	0	7.2	.2	7.4	0	7.4	100.0
June	0	0	3.0	1.0	4.0	0	4.0	100.0
July	3	0	8.6	2.9	14.5	1	13.5	93.1
August	1	0	7.7	2.6	11.3	0	11.3	100.0
September	6	0	7.8	2.6	16.4	4	12.4	75.6
ANNUAL TOTALS	34	0	41.7	14.2	89.9	16	73.9	82.2

ASH SLOUGH MARSH NUTRIENT BUDGET

1980-81

INORGANIC N (Kilograms)

West Watershed Loads + East Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Inorganic N West Watershed	Inorganic N East Watershed	Inorganic N Rainfall	Inorganic N Ungaged Runoff	Total Inorganic N In	Inorganic N Out	Source-/Sink+	%
October	0	0	0.5	0.2	0.7	0	0.7	100.0
November	0	0	3.8	1.3	5.1	0	5.1	100.0
December	0	0	0.8	0.3	1.1	0	1.1	100.0
January	0	0	0	0	0	0	0	100.0
February	0	0	2.8	0.9	3.7	0	3.7	100.0
March	0	0	0.7	0.2	0.9	0	0.9	100.0
April	0	0	0	0	0	0	0	100.0
May	0	0	1.4	0.5	1.9	0	1.9	100.0
June	0	0	2.3	0.8	3.1	0	3.1	100.0
July	0	0	5.0	1.7	6.7	0	6.7	100.0
August	0	0	6.8	2.3	9.1	0	9.1	100.0
September	0	0	4.3	1.5	5.8	0	5.8	100.0
ANNUAL TOTALS	0	0	28.5	9.7	38.2	0	38.2	100.0

ASH SLOUGH MARSH NUTRIENT BUDGET

1981-82

INORGANIC N (Kilograms)

West Watershed Loads + East Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Inorganic N West Watershed	Inorganic N East Watershed	Inorganic N Rainfall	Inorganic N Ungaged Runoff	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	0	0	0.6	0.2	0.8	0	0.8	100.0
November	0	0	0.9	0.3	1.2	0	1.2	100.0
December	0	0	0	0	0	0	0	100.0
January	0	0	1.2	0.4	1.6	0	1.6	100.0
February	0	0	2.6	0.9	3.5	0	3.5	100.0
March	4	0	1.8	0.6	6.4	1	5.4	84.4
April	14	0	3.0	1.0	18.0	11	7.0	38.9
May	0	0	3.5	1.2	4.7	1	3.7	78.7
June	12	0	6.6	2.2	20.8	14	6.8	32.7
July	4	0	5.4	1.8	11.2	23	-11.8	-105.4
August	1	0	6.1	2.1	9.2	5	4.2	45.7
September	11	0	7.6	2.6	21.2	5	16.2	76.4
ANNUAL TOTALS	46	0	39.3	3.3	98.6	60	38.6	39.1

ASH SLOUGH MARSH NUTRIENT BUDGET

1979-80

TOTAL N (Kilograms)

West Watershed Loads + East Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Total N West Watershed	Total N East Watershed	Total N Rainfall	Total N Ungaged Runoff	Total N In	Total N Out	Source-/Sink +	%
October	64	18	1.3	0.5	83.8	134	-50.2	-59.5
November	0	0	1.1	0.4	1.5	2	-.5	-33.3
December	0	0	4.5	1.5	6.0	0	6.0	100.0
January	0	2	4.3	1.5	7.8	3	4.8	61.5
February	34	14	5.6	1.9	55.5	47	. 8.5	15.3
March	22	4	5.9	2.0	33.9	70	-36.1	-106.5
April	324	2	8.3	2.8	337.1	184	153.1	45.4
May	0	0	1.6	0.5	2.1	0	2.1	100.0
June	0	0	6.7	2.3	9.0	0	9.0	100.0
July	149	2	19.3	6.5	176.8	26	151.8	85.3
August	43	1	17.1	5.8	66.9	37	30.0	44.8
September	263	18	17.4	5.9	304.3	279	25.3	82.2
ANNUAL TOTALS	899	61	93.1	31.6	1085	782	303	27.9

ASH SLOUGH MARSH NUTRIENT BUDGET

1980-81

TOTAL N (Kilograms)

West Watershed Loads + East Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Total N West Watershed	Total N East Watershed	Total N Rainfall	Total N Ungaged Runoff	Total N In	Total N Out	Source-/Sink +	%
October	0	0	1.1	0.4	1.5	0	1.5	100.0
November	0	0	8.6	2.9	11.5	0	11.5	100.0
December	0	0	1.9	0.6	2.5	0	2.5	100.0
January	0	0	0	0	0	0	0	-
February	0	0	6.2	2.1	8.3	0	8.3	100.0
March	0	0	1.6	0.5	2.1	0	2.1	100.0
April	0	0	0	0	0	0	0	-
May	0	0	3.2	1.1	4.3	0	4.3	100.0
June	0	0	5.1	1.7	6.8	0	6.8	100.0
July	0	0	11.2	3.8	15.0	0	15.0	100.0
August	0	0	15.2	5.2	20.4	0	20.4	100.0
September	9	1	9.6	3.3	22.9	0	22.9	100.0
ANNUAL TOTALS	9	1	63.7	21.6	95.3	0	95.3	100.0

ASH SLOUGH MARSH NUTRIENT BUDGET

1981-82

TOTAL N (Kilograms)

West Watershed Loads + East Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Total N West Watershed	Total N East Watershed	Total N Rainfall	Total N Ungaged Runoff	Total N In	Total N Out	Source-/Sink +	%
October	0	0	1.3	0.5	1.8	0	1.8	100.0
November	0	0	2.0	0.7	2.7	0	2.7	100.0
December	0	0	0	0	0	0	0	-
January	0	0	2.8	0.9	3.7	0	3.7	100.0
February	0	0	5.9	2.0	7.9	0	7.9	100.0
March	93	0	4.0	1.4	98.4	45	53.4	54.1
April	386	6	6.7	2.3	401.0	349	52.0	13.0
May	4	2	7.8	2.6	16.4	87	-70.6	-443.8
June	322	18	14.7	5.0	359.7	263	96.4	26.9
July	204	7	12.0	4.1	227.1	252	-24.9	-11.0
August	92	5	13.6	4.6	115.2	161	-45.8	-40.0
September	161	9	16.9	5.7	192.6	217	-24.4	-12.4
ANNUAL TOTALS	1,262	47	87.6	29.7	1,426.3	1,374	52.3	3.6

ASH SLOUGH MARSH NUTRIENT BUDGET

1979-80

ORTHO P (Kilograms)

West Watershed Loads + East Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Ortho P West Watershed	Ortho P East Watershed	Ortho P Rainfall	Ortho P Ungauged Runoff	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	17	2	.05	.02	19.1	21	-1.9	-10.1
November	0	0	.04	.01	.1	0	.1	100.0
December	0	0	.18	.06	.2	0	.2	100.0
January	0	0	.17	.06	.2	1	.1	-291.3
February	68	2	.22	.07	70.3	41	29.3	41.7
March	13	1	.23	.08	14.3	29	-14.7	-102.7
April	149	1	.32	.11	150.4	71	79.4	52.8
May	0	0	.06	.02	.1	0	.1	100.0
June	0	0	.26	.09	.4	0	.4	100.0
July	74	0	.75	.25	75.0	13	62.0	82.7
August	25	0	.67	.23	25.9	6	19.9	76.8
September	119	2	.68	.23	121.9	86	35.9	29.5
ANNUAL TOTALS	465	9	3.63	1.23	478.9	268	210.9	44.0

ASH SLOUGH MARSH NUTRIENT BUDGET

1980-81

ORTHO P (Kilograms)

West Watershed Loads + East Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Ortho P West Watershed	Ortho P East Watershed	Ortho P Rainfall	Ortho P Ungaged Runoff	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	0	0	.04	.01	.05	0	.05	100.0
November	0	0	.33	.11	.44	0	.44	100.0
December	0	0	.07	.02	.09	0	.09	100.0
January	0	0	0	0	0	0	0	-
February	0	0	.24	.08	.32	0	.32	100.0
March	0	0	.06	.02	.08	0	.08	100.0
April	0	0	0	0	0	0	0	-
May	0	0	.13	.04	.17	0	.17	100.0
June	0	0	.20	.07	.27	0	.27	100.0
July	0	0	.44	.15	.59	0	.59	100.0
August	0	0	.59	.20	.79	0	.79	100.0
September	2	0	.38	.13	.51	0	.51	100.0
ANNUAL TOTALS	2	0	2.48	.84	5.32	0	5.32	100.0

ASH SLOUGH MARSH NUTRIENT BUDGET

1981-82

ORTHO P (Kilograms)

West Watershed Loads + East Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Ortho P West Watershed	Ortho P East Watershed	Ortho P Rainfall	Ortho P Ungaged Runoff	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	0	0	.1	0	.1	0	.1	100.0
November	0	0	.1	0	.1	0	.1	100.0
December	0	0	0	0	0	0	0	-
January	0	0	.1	0	.2	0	.2	100.0
February	0	0	.2	.1	.3	0	.3	100.0
March	67	0	.2	.1	67.2	19	48.2	71.7
April	200	1	.2	.1	201.4	150	51.4	25.5
May	1	0	.3	.1	1.4	18	-16.6	-1,185.7
June	78	2	.6	.2	80.8	29	51.8	64.1
July	29	0	.5	.2	29.6	19	10.6	35.9
August	9	0	.5	.2	9.7	5	4.7	48.5
September	17	0	.7	.2	17.9	7	10.9	60.9
ANNUAL TOTALS	401	3	3.4	1.2	408.6	247	161.6	39.5

ASH SLOUGH MARSH NUTRIENT BUDGET

1979-80

TOTAL P (Kilograms)

West Watershed Loads + East Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Total P West Watershed	Total P East Watershed	Total P Rainfall	Total P Ungaged Runoff	Total P In	Total P Out	Source- /Sink +	%
October	20	3	.1	0	23.1	29	-5.9	-25.5
November	0	0	.1	0	.1	0	.1	100.0
December	0	0	.3	.1	.4	0	.4	100.0
January	0	0	.3	.1	.4	1	-.6	-177.8
February	73	3	.4	.1	76.5	46	30.5	39.8
March	15	1	.4	.1	16.5	34	-17.5	-106.2
April	189	1	.5	.2	190.7	86	104.7	54.9
May	0	0	.1	0	.1	0	.1	100.0
June	0	0	.4	.1	.6	0	.6	100.0
July	86	0	1.2	.4	87.6	15	72.6	82.9
August	28	0	1.1	.4	29.4	7	22.4	76.2
September	132	4	1.1	.4	137.5	99	38.5	28.0
ANNUAL TOTALS	543	12	5.8	2.0	563	317	246	43.7

ASH SLOUGH MARSH NUTRIENT BUDGET

1980-81

TOTAL P (Kilograms)

West Watershed Loads + East Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Total P West Watershed	Total P East Watershed	Total P Rainfall	Total P Ungaged Runoff	Total P In	Total P Out	Source-/Sink +	%
October	0	0	.1	0	.1	0	.1	100.0
November	0	0	.5	.2	.7	0	.7	100.0
December	0	0	.1	0	.2	0	.2	100.0
January	0	0	0	0	0	0	0	-
February	0	0	.4	.1	.5	0	.5	100.0
March	0	0	.1	0	.1	0	.1	100.0
April	0	0	0	0	0	0	0	-
May	0	0	.2	.1	.3	0	.3	100.0
June	0	0	.3	.1	.4	0	.4	100.0
July	0	0	.7	.2	.9	0	.9	100.0
August	0	0	1.0	.3	1.3	0	1.3	100.0
September	2	0	.6	.2	2.8	0	2.8	100.0
ANNUAL TOTALS	2	0	4.0	1.4	7.3	0	7.3	100.0

ASH SLOUGH MARSH NUTRIENT BUDGET

1981-82

TOTAL P (Kilograms)

West Watershed Loads + East Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Total P West Watershed	Total P East Watershed	Total P Rainfall	Total P Ungaged Runoff	Total P In	Total P Out	Source-/Sink +	%
October	0	0	.1	0	.1	0	.1	100.0
November	0	0	.1	0	.1	0	.1	100.0
December	0	0	0	0	0	0	0	-
January	0	0	.2	.1	.2	0	.2	100.0
February	0	0	.4	.1	.5	0	.5	100.0
March	70	0	.3	.1	70.3	19	51.3	73.0
April	221	1	.4	.1	222.6	169	53.6	24.1
May	1	0	.5	.2	1.6	22	-20.4	-1,241.5
June	100	3	.9	.3	104.2	46	58.2	55.9
July	43	0	.8	.3	44.0	33	11.0	25.0
August	15	0	.9	.3	16.1	13	3.1	19.4
September	27	0	1.1	.4	28.4	20	8.4	29.6
ANNUAL TOTALS	477	4	5.5	1.9	488.3	322	166.3	34.1

ARMSTRONG SLOUGH MARSH WATER BUDGET

(Cubic Meters)

1979-80

North Watershed Loads + South Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Flow In North Watershed	Flow In South Watershed	Rainfall On Marsh Surface	Runoff From Ungaged Area	Total Flow In	Total Flow Out	Net Uptake+/ Discharge-
October	3,877,274	437,007	363	786	4,315,430	46,490	4,268,940
November	168,343	27,649	2,214	4,719	202,925	145,587	57,338
December	131,895	29,851	8,482	18,351	188,579	131,395	57,184
January	111,576	17,862	5,530	11,981	146,949	94,204	52,745
February	313,442	105,948	8,857	19,190	447,437	452,177	-4,740
March	275,270	101,544	5,530	11,981	394,325	348,695	45,630
April	136,535	57,501	6,268	13,580	213,884	408,379	-194,495
May	216,546	1,958	13,649	29,572	261,725	298,760	-37,035
June	92,980	12,234	13,274	28,760	147,248	144,609	2,639
July	105,948	17,617	26,184	56,731	206,480	85,885	120,595
August	667,255	154,396	12,911	27,973	862,535	856,151	6,384
September	181,311	96,161	8,482	18,377	304,331	174,215	130,116
ANNUAL TOTALS	6,278,375	1,059,728	111,744	242,106	7,691,953	3,186,527	4,505,426

ARMSTRONG SLOUGH MARSH WATER BUDGET

(Cubic Meters)

1980-81

North Watershed Loads + South Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Flow In North Watershed	Flow In South Watershed	Rainfall On Marsh Surface	Runoff From Ungaged Area	Total Flow In	Total Flow Out	Source-/Sink +
October	116,715	6,852	2,214	8,405	134,186	0	134,186
November	128,459	3,182	9,958	37,804	179,403	374,612	-195,209
December	130,173	3,182	3,315	12,585	149,255	377,548	-228,293
January	95,672	14,926	738	15,387	126,723	0	126,723
February	184,247	84,905	7,006	26,597	302,755	15,905	286,850
March	119,651	35,724	4,054	15,390	174,819	3,426	171,393
April	152,684	244	0	0	152,928	0	152,928
May	119,895	0	8,482	32,201	160,578	0	160,578
June	140,694	0	13,649	51,817	206,160	132,863	73,297
July	46,490	0	14,012	53,195	113,697	0	113,697
August	1,507,772	33,522	34,667	131,609	1,707,570	1,362,404	345,166
September	4,951,195	1,741,666	18,077	68,627	6,779,565	4,862,374	1,917,191
ANNUAL TOTALS	7,693,647	1,924,203	116,172	441,031	10,175,053	7,129,132	3,045,921

ARMSTRONG SLOUGH MARSH WATER BUDGET

(Cubic Meters)

1981-82

North Watershed Loads + South Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Flow In North Watershed	Flow In South Watershed	Rainfall On Marsh Surface	Runoff From Ungaged Area	Total Flow In	Total Flow Out	Source-/Sink +
October	309,526	56,522	7,006	91,747	464,801	458,050	6,751
November	276,004	93,714	4,429	58,000	432,147	496,465	-64,318
December	94,693	0	0	0	94,693	447,773	-182,045
January	98,363	0	4,429	58,000	160,792	276,738	-115,946
February	211,408	23,979	8,482	111,076	354,945	695,149	-340,204
March	271,110	166,630	14,012	183,495	635,247	1,184,519	-549,272
April	1,100,592	919,035	10,321	135,159	2,165,107	1,187,699	977,408
May	752,650	212,142	14,750	193,159	1,172,701	1,364,852	-192,151
June	3,794,815	2,613,477	38,357	502,306	6,948,955	5,691,611	1,257,344
July	2,048,010	995,622	14,750	193,159	3,251,541	5,045,153	-1,793,612
August	2,343,835	1,276,275	31,351	410,558	4,062,019	5,323,605	-1,261,586
September	4,613,040	3,372,978	22,494	294,571	8,303,083	8,508,175	-205,092
ANNUAL TOTALS	15,914,046	9,730,374	170,381	2,231,231	28,046,032	30,679,789	-2,633,757

ARMSTRONG SLOUGH MARSH NUTRIENT BUDGET

1979-80

INORGANIC N (Kilograms)

North Watershed Loads + South Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Inorganic N North Watershed	Inorganic N South Watershed	Inorganic N Rainfall	Inorganic N Ungaged Rainfall	Total Inorganic N In	Inorganic N Out	Source-/Sink	%
October	430	11	-	-	441	3	438	99.3
November	12	1	.1	.2	13.3	10	3.3	24.8
December	3	1	.5	1.1	5.6	5	.6	10.7
January	3	0	.3	.6	3.9	2	1.9	48.7
February	6	10	.5	1.1	17.6	13	4.6	26.1
March	6	16	.3	.6	22.9	14	8.9	38.9
April	3	12	.4	.9	16.3	18	-1.7	-10.4
May	5	0	.8	1.7	7.5	10	-2.5	-33.3
June	3	0	.8	1.7	5.5	3	2.5	45.5
July	9	0	1.6	3.5	14.1	2	12.1	85.8
August	105	2	.8	1.7	109.5	13	96.5	88.1
September	20	2	.5	1.1	23.6	2	21.6	91.5
ANNUAL TOTALS	605	55	6.6	14.2	680.8	95	585.8	86.0

ARMSTRONG SLOUGH MARSH NUTRIENT BUDGET

1980-81

INORGANIC N (Kilograms)

North Watershed Loads + South Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Inorganic N North Watershed	Inorganic N South Watershed	Inorganic N Rainfall	Inorganic N Ungaged Runoff	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	8	0	.1	.4	8.5	0	8.5	100.0
November	9	0	.6	2.3	11.9	4	7.9	66.4
December	10	0	.2	.8	11.0	4	7.0	63.6
January	8	0	-	-	8.0	0	8.0	100.0
February	6	1	.4	1.5	8.9	0	8.9	100.0
March	2	0	.2	.8	3.0	0	3.0	100.0
April	3	0	-	-	3.0	0	3.0	100.0
May	3	0	.5	1.9	5.4	0	5.4	100.0
June	5	0	.8	3.0	8.8	1	7.8	88.6
July	21	0	.8	3.0	24.8	0	24.8	100.0
August	277	2	2.1	4.5	285.6	87	198.6	69.5
September	1,231	104	1.1	4.2	1,340.3	496	844.3	63.0
ANNUAL TOTALS	1,583	107	6.8	22.4	1,719.2	592	1,127.2	65.6

ARMSTRONG SLOUGH MARSH NUTRIENT BUDGET

1981-82

INORGANIC N (Kilograms)

North Watershed Loads + South Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Inorganic N North Watershed	Inorganic N South Watershed	Inorganic N Rainfall	Inorganic N Ungaged Runoff	Total Inorganic N In	Inorganic N Out	Source-/Sink +	%
October	68	3	.4	5.2	76.6	93	-16.4	-21.4
November	45	3	.3	3.9	52.2	37	15.2	29.1
December	5	0	-	-	5.0	20	-15.0	-300.0
January	8	0	.3	3.9	12.2	19	-6.8	-55.7
February	14	2	.5	6.5	23.0	14	9.0	39.1
March	20	4	.8	10.5	35.3	59	-23.7	-67.1
April	35	23	.6	7.9	66.5	33	33.5	50.4
May	19	3	.9	11.8	34.7	36	-1.3	-3.7
June	270	51	2.3	30.1	353.4	95	258.4	73.1
July	134	16	.9	11.8	162.7	63	99.7	61.3
August	220	16	1.9	24.9	262.8	73	189.8	72.2
September	401	50	1.3	17.0	469.3	223	246.3	52.5
ANNUAL TOTALS	1,239	171	10.2	133.5	1,553.7	765	788.7	50.8

ARMSTRONG SLOUGH MARSH NUTRIENT BUDGET

1979-80

TOTAL N (Kilograms)

North Watershed Loads + South Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Total N North Watershed	Total N South Watershed	Total N Rainfall	Total N Ungaged Runoff	Total N In	Total N Out	Source- /Sink +	%
October	6,243	621	1	2.2	6,867	69	6,798	99.0
November	169	37	3	6.5	216	161	55	25.2
December	112	40	13	28.1	193	104	89	46.1
January	155	22	9	19.5	206	73	133	64.6
February	570	134	14	30.3	748	448	300	40.1
March	374	180	9	19.5	583	419	164	28.1
April	150	138	10	21.7	320	559	-239	-74.7
May	174	3	21	45.5	244	411	-167	-68.4
June	101	26	20	43.3	190	146	44	23.2
July	120	25	40	86.6	272	68	204	75.0
August	1,261	204	20	43.3	1,528	1,413	115	7.5
September	178	91	13	28.1	310	198	112	36.2
ANNUAL TOTALS	9,607	1,521	173	374.6	11,676	4,069	7,607	65.2

ARMSTRONG SLOUGH MARSH NUTRIENT BUDGET

1980-81

TOTAL N (Kilograms)

North Watershed Loads + South Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Total N North Watershed	Total N South Watershed	Total N Rainfall	Total N Ungaged Runoff	Total N In	Total N Out	Source-/Sink +	%
October	88	8	3	11.4	110	0	110	100.0
November	87	5	15	56.9	164	310	-146	-89.0
December	97	3	5	19.0	124	247	-123	-99.2
January	74	14	1	3.8	93	0	93	100.0
February	147	100	11	41.8	300	13	287	95.7
March	97	50	6	22.8	176	3	173	98.3
April	137	0	0	0	137	0	137	100.0
May	134	0	13	49.4	196	0	196	100.0
June	113	0	21	79.7	214	156	58	27.1
July	79	0	22	83.5	185	0	185	100.0
August	3,552	80	53	201.2	3,886	3,692	194	5.0
September	15,723	4,370	28	106.3	20,227	13,131	7,096	35.1
ANNUAL TOTALS	20,328	4,630	178	675.7	25,812	17,552	8,260	32.0

ARMSTRONG SLOUGH MARSH NUTRIENT BUDGET

1981-82

TOTAL N (Kilograms)

North Watershed Loads + South Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Total N North Watershed	Total N South Watershed	Total N Rainfall	Total N Ungaged Runoff	Total N In	Total N Out	Source- /Sink +	%
October	722	144	11	144	1,021	977	44	4.3
November	668	199	7	92	966	868	98	10.1
December	94	0	0	0	94	558	-464	-493.6
January	94	0	7	92	193	258	-65	-33.7
February	369	59	13	170	611	1,031	-420	-68.7
March	487	336	22	288	1,133	2,072	-939	-82.9
April	2,057	1,609	16	210	3,892	1,988	1,904	48.9
May	1,096	368	23	301	1,788	2,013	-225	-12.6
June	6,127	3,702	59	773	10,661	8,809	1,852	17.4
July	3,164	1,237	23	301	4,725	7,651	-2,926	-61.9
August	4,553	1,674	48	629	6,904	7,628	-724	-10.5
September	6,757	3,703	35	458	10,953	11,335	-382	-3.5
ANNUAL TOTALS	26,188	13,031	264	3,457	42,940	45,188	-2,248	-5.2

ARMSTRONG SLOUGH MARSH NUTRIENT BUDGET

1979-80

ORTHO P (Kilograms)

North Watershed Loads + South Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Ortho P North Watershed	Ortho P South Watershed	Ortho P Rainfall	Ortho P Ungaged Runoff	Total Ortho P In	Ortho P Out	Source- /Sink +	%
October	296	6	-	-	302	3	299	99.0
November	5	0	.1	.2	5.3	5	.3	5.7
December	2	1	.5	1.1	4.6	3	1.6	34.8
January	2	0	.3	.6	2.9	2	.9	31.0
February	6	2	.5	1.1	9.6	8	1.6	16.7
March	9	1	.3	.6	10.9	14	-3.1	-28.4
April	4	1	.4	.9	6.3	16	-9.7	-154.0
May	5	0	.8	1.7	7.5	3	4.5	60.0
June	2	0	.8	1.7	4.5	2	2.5	55.6
July	3	0	1.6	3.5	8.1	1	7.1	87.7
August	40	2	.8	1.7	44.5	9	35.5	79.8
September	9	1	.5	1.1	11.6	4	7.6	65.5
ANNUAL TOTALS	383	14	6.7	14.5	418.2	70	348.2	83.3

ARMSTRONG SLOUGH MARSH NUTRIENT BUDGET

1980-81

ORTHO P (Kilograms)

North Watershed Loads + South Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Ortho P North Watershed	Ortho P South Watershed	Ortho P Rainfall	Ortho P Ungaged Runoff	Total Ortho P In	Ortho P Out	Source-/Sink +	%
October	3	0	.1	.4	3.5	0	3.5	100.0
November	3	0	.6	2.3	5.9	4	1.9	32.2
December	3	0	.2	.8	4.0	4	0	0
January	3	0	-	-	3.0	0	3.0	100.0
February	6	1	.4	1.5	8.9	0	8.9	100.0
March	3	0	.2	.8	4.0	0	4.0	100.0
April	4	0	-	-	4.0	0	4.0	100.0
May	3	0	.5	1.9	5.4	0	5.4	100.0
June	4	0	.8	3.0	7.8	1	6.8	87.2
July	2	0	.8	3.0	5.8	0	5.8	100.0
August	479	4	2.1	8.0	493.1	383	110.1	22.3
September	1,639	101	1.1	4.2	1,745.3	943	802.3	46.0
ANNUAL TOTALS	2,152	106	7.0	26.6	2,291.6	1,335	956.6	41.7

ARMSTRONG SLOUGH MARSH NUTRIENT BUDGET

1981-82

ORTHO P (Kilograms)

North Watershed Loads + South Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Ortho P North Watershed	Ortho P South Watershed	Ortho P Rainfall	Ortho P Ungaged Runoff	Ortho P In	Ortho P Out	Source- /Sink +	%
October	30	2	.4	5.2	37.6	24	13.6	36.2
November	17	1	.3	3.9	22.2	24	-1.8	-8.1
December	2	0	-	-	2.0	13	-11.0	-550.0
January	2	0	.3	3.9	6.2	11	-4.8	-77.4
February	11	2	.5	6.5	20.0	45	-25.0	-125.0
March	10	3	.8	10.5	24.3	94	-69.7	-286.8
April	26	17	.6	7.9	51.5	29	22.5	43.7
May	22	4	.9	11.8	38.7	22	16.7	43.2
June	125	42	2.3	30.1	199.4	113	86.4	43.3
July	37	9	.9	11.8	58.7	79	-20.3	-34.6
August	35	5	1.9	24.9	66.8	48	18.8	28.1
September	67	23	1.3	17.0	108.3	110	-1.7	-1.6
ANNUAL TOTALS	384	107	10.2	133.6	634.8	612	22.8	3.6

ARMSTRONG SLOUGH MARSH NUTRIENT BUDGET

1979-80

TOTAL P (Kilograms)

North Watershed Loads + South Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Total P North Watershed	Total P South Watershed	Total P Rainfall	Total P Ungaged Runoff	Total P In	Total P Out	Source-/Sink +	%
October	637	19	-	-	656	6	650	99.1
November	14	1	.2	.4	15.6	12	3.6	23.1
December	7	2	.8	1.7	11.5	7	4.5	39.1
January	16	1	.5	1.1	18.6	6	12.6	67.7
February	33	10	.9	1.9	45.8	22	23.8	52.0
March	23	8	.5	1.1	32.6	31	1.6	4.9
April	9	9	.6	1.3	19.9	44	-24.1	-121.1
May	11	0	1.3	2.8	15.1	13	2.1	13.9
June	6	1	1.3	2.8	11.1	5	6.1	55.0
July	7	1	2.5	5.4	15.9	3	12.9	81.1
August	77	4	1.2	2.6	84.8	41	43.8	51.7
September	18	3	.8	1.7	23.5	8	15.5	66.0
ANNUAL TOTALS	858	59	10.7	23.2	950.4	198	752.9	79.2

ARMSTRONG SLOUGH MARSH NUTRIENT BUDGET

1980-81

TOTAL P (Kilograms)

North Watershed Loads + South Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Total P North Watershed	Total P South Watershed	Total P Rainfall	Total P Ungaged Runoff	Total P In	Total P Out	Source-/Sink +	%
October	10	0	.2	.8	11.0	0	11.0	100.0
November	7	0	1.0	3.8	11.8	9	2.8	31.1
December	6	0	.3	1.1	7.4	4	3.4	45.9
January	7	0	.1	.4	7.5	0	7.5	100.0
February	12	3	.7	2.7	18.4	0	18.4	100.0
March	6	2	.4	1.5	9.9	0	9.9	100.0
April	7	0	0	0	7.0	0	7.0	100.0
May	7	0	.8	3.0	10.8	0	10.8	100.0
June	10	0	1.3	4.9	16.2	7	9.2	56.8
July	5	0	1.3	4.9	11.2	0	11.2	100.0
August	654	7	3.3	12.5	676.8	490	186.8	27.6
September	2,352	236	1.7	6.5	2,597.3	1,420	1,177.3	45.3
ANNUAL TOTALS	3,084	248	11.2	42.5	3,385.7	1,930	1,455.7	43.0

ARMSTRONG SLOUGH MARSH NUTRIENT BUDGET

1981-82

TOTAL P (Kilograms)

North Watershed Loads + South Watershed Loads + Rainfall Loads + Runoff = Total Flow In - Total Flow Out = Uptake/Discharge

Month	Total P North Watershed	Total P South Watershed	Total P Rainfall	Total P Ungaged Runoff	Total P In	Total P Out	Source-/Sink +	%
October	51	6	.7	9.2	66.9	51	15.9	23.8
November	42	5	.4	5.2	52.6	45	7.6	14.4
December	5	0	0	0	5.0	19	-14.0	-280.0
January	6	0	.4	5.2	11.6	18	-6.4	-55.2
February	23	5	.8	10.5	39.3	107	-67.7	-172.3
March	26	12	1.3	17.0	56.3	180	-123.7	-219.7
April	94	66	1.0	13.1	174.1	90	84.1	48.3
May	52	15	1.4	18.3	86.7	81	5.7	6.6
June	30	153	3.7	48.5	235.2	394	-158.8	-67.5
July	133	40	1.4	18.3	192.7	286	-93.3	-48.4
August	133	43	3.0	39.3	218.3	276	-57.7	-26.4
September	286	89	2.2	28.8	406.0	387	19.0	4.7
ANNUAL TOTALS	881	434	16.4	214.8	1,546.2	1,934	-387.8	-25.1

APPENDIX III

Site Comparison Data Summary

IIIa Annual Flow Weighted Concentrations in Export Upland Demonstration Project Sites.

IIIb Annual Loading Rates On Upland Demonstration Project Watersheds

IIIc Annual Uptake Rates On Upland Demonstration Project Watersheds

IIId Annual Export Rates Upland Demonstration Project Watersheds

IIIe Annual Loading And Uptake Rates Armstrong Slough Marsh

IIIf Annual Loading And Uptake Rates Ash Slough Marsh

IIIa

ANNUAL FLOW WEIGHTED CONCENTRATIONS IN EXPORT UPLAND DEMONSTRATION PROJECT SITES

(mg/L)

INORGANIC N

Site/Watershed	1979-80	1980-81	1981-82	Annual Average
Armstrong Slough North	0.096	0.205	0.078	0.126
Armstrong Slough South	0.052	0.056	0.018	0.042
Peavine	0.016	0.030	0.022	0.023
Wildcat East	0.011	0.031	0.028	0.023
Wildcat West	0.075	0.065	0.032	0.057
Wildcat All	0.040	0.030	0.030	0.033
Ash Slough East	0.000	0.000	0.000	0.000*
Ash Slough West	0.080	0.000	0.080	0.053
SEZ Dairy	2.010	0.540	1.380	1.310

TOTAL N

Site/Watershed	1979-80	1980-81	1981-82	Annual Average
Armstrong Slough North	1.530	2.640	1.650	1.940
Armstrong Slough South	1.440	2.410	1.340	1.730
Peavine	1.540	2.310	1.690	1.847
Wildcat East	1.038	1.905	1.739	1.561
Wildcat West	2.943	2.414	2.673	2.677
Wildcat All	1.350	1.270	2.420	1.680
Ash Slough East	1.930	Trace	1.780	1.855*
Ash Slough West	2.070	3.070	2.200	2.447
SEZ Dairy	6.090	3.700	4.270	4.687

*Second Year Eliminated From Calculation Of Average

ORTHO P

Site/Watershed	1979-80	1980-81	1981-82	Annual Average
Armstrong Slough North	0.061	0.280	0.024	0.122
Armstrong Slough South	0.013	0.055	0.011	0.026
Peavine	0.010	0.026	0.006	0.014
Wildcat East	0.015	0.003	0.009	0.009
Wildcat West	0.013	0.010	0.005	0.009
Wildcat All	0.010	0.010	0.010	0.010
Ash Slough East	0.290	0.000	0.144	0.202*
Ash Slough West	1.070	0.680	0.720	0.823
SEZ Dairy	2.190	1.900	1.460	1.850

TOTAL P

Site/Watershed	1979-80	1980-81	1981-82	Annual Average
Armstrong Slough North	0.137	0.401	0.055	0.198
Armstrong Slough South	0.056	0.129	0.045	0.077
Peavine	0.032	0.010	0.036	0.026
Wildcat East	0.022	0.030	0.020	0.024
Wildcat West	0.113	0.088	0.059	0.087
Wildcat All	0.030	0.060	0.100	0.063
Ash Slough East	0.380	0.000	0.150	0.265*
Ash Slough West	1.250	0.680	0.850	0.927
SEZ Dairy	3.100	2.270	1.710	2.360

*Second Year Eliminated From Calculation Of Average

IIIb

ANNUAL LOADING RATES ON UPLAND DEMONSTRATION PROJECT WATERSHEDS

(kg/ha/yr)

INORGANIC N

Site/Watershed	1979-80	1980-81	1981-82	Annual Average
Armstrong Slough North	188.8	189	192	189.9
Armstrong Slough South	48.1	48.8	51.4	49.3
Peavine	90.7	91.7	94.8	92.4
Wildcat East	4.9	5.8	6.9	5.9
Wildcat West	4.9	5.8	6.9	5.9
Wildcat All	4.9	5.8	6.9	5.9
Ash Slough East	7.1	4.9	6.4	6.1
Ash Slough West	74.5	72.2	74.1	73.6
SEZ Dairy	246.6	250.7	253.9	250.4

TOTAL N

Site/Watershed	1979-80	1980-81	1981-82	Annual Average
Armstrong Slough North	196.8	197.4	204.3	199.5
Armstrong Slough South	56.2	56.7	63.9	58.9
Peavine	95.7	97.9	88.8	94.1
Wildcat East	11.4	13.4	15.8	13.5
Wildcat West	11.4	13.4	15.8	13.5
Wildcat All	11.4	13.4	15.8	13.5
Ash Slough East	16.3	11.2	14.8	14.1
Ash Slough West	83.7	78.5	82.7	81.6
SEZ Dairy	255.6	264.6	271.6	263.9

ORTHO P

Site/Watershed	1979-80	1980-81	1981-82	Annual Average
Armstrong Slough North	20.8	20.8	21.1	20.9
Armstrong Slough South	11	11.1	11.3	11.1
Peavine	22.1	22.2	22.4	22.2
Wildcat East	0.4	0.5	0.6	0.5
Wildcat West	0.4	0.5	0.6	0.5
Wildcat All	0.4	0.5	0.6	0.5
Ash Slough East	0.6	0.4	0.6	0.5
Ash Slough West	34.3	34.1	34.3	34.2
SEZ Dairy	51	51.5	51.8	51.4

TOTAL P

Site/Watershed	1979-80	1980-81	1981-82	Annual Average
Armstrong Slough North	21.1	21.2	21.6	21.3
Armstrong Slough South	11.4	11.4	11.8	11.5
Peavine	22.3	22.4	22.9	22.5
Wildcat East	0.7	0.8	1	0.8
Wildcat West	0.7	0.8	1	0.8
Wildcat All	0.7	0.8	1	0.8
Ash Slough East	1.1	0.7	0.9	0.9
Ash Slough West	34.7	34.4	34.7	34.6
SEZ Dairy	52	53	53.8	52.9

IIIc

ANNUAL UPTAKE RATES ON UPLAND DEMONSTRATION PROJECT WATERSHEDS

(kg/ha/yr)

INORGANIC N

Site/Watershed	1979-80	1980-81	1981-82	Annual Average
Armstrong Slough North	188.60	188.50	191.60	189.60
Armstrong Slough South	48.06	48.26	51.20	49.17
Peavine	90.70	91.60	94.60	92.30
Wildcat East	4.93	5.80	6.84	5.86
Wildcat West	4.91	5.79	6.87	5.86
Wildcat All	1.56	1.92	2.23	1.90
Ash Slough East	7.10	4.90	6.40	6.10
Ash Slough West	74.00	72.20	73.40	73.20
SEZ Dairy	244.00	249.50	244.50	246.00

TOTAL N

Site/Watershed	1979-80	1980-81	1981-82	Annual Average
Armstrong Slough North	194.00	191.00	196.00	193.70
Armstrong Slough South	54.70	52.10	50.70	52.50
Peavine	93.79	91.21	72.99	86.00
Wildcat East	10.37	12.38	13.45	12.07
Wildcat West	10.15	12.52	15.16	12.61
Wildcat All	2.16	4.93	2.74	3.28
Ash Slough East	13.30	11.10	12.50	12.30
Ash Slough West	70.70	78.40	64.40	71.20
SEZ Dairy	248.20	256.30	242.50	249.00

ORTHO P

Site/Watershed	1979-80	1980-81	1981-82	Annual Average
Armstrong Slough North	20.70	20.10	21.00	20.60
Armstrong Slough South	11.02	11.00	11.22	11.08
Peavine	22.10	22.10	22.40	22.20
Wildcat East	0.43	0.52	0.60	0.52
Wildcat West	0.44	0.52	0.61	0.52
Wildcat All	0.13	0.17	0.20	0.17
Ash Slough East	0.19	0.44	0.43	0.35
Ash Slough West	27.60	34.10	28.50	30.10
SEZ Dairy	48.20	36.20	41.90	42.10

TOTAL P

Site/Watershed	1979-80	1980-81	1981-82	Annual Average
Armstrong Slough North	20.90	20.20	21.30	20.80
Armstrong Slough South	11.30	11.16	11.41	11.20
Peavine	22.20	22.10	22.50	22.30
Wildcat East	0.69	0.82	0.95	0.82
Wildcat West	0.66	0.82	0.97	0.82
Wildcat All	0.20	0.28	0.19	0.22
Ash Slough East	0.42	0.70	0.73	0.62
Ash Slough West	26.80	34.40	27.70	29.60
SEZ Dairy	48.20	47.90	42.10	46.10

ANNUAL EXPORT RATES FROM UPLAND DEMONSTRATION PROJECT WATERSHEDS

(kg/ha/yr)

INORGANIC N

Site/Watershed	1979-80	1980-81	1981-82	Annual Average
Armstrong Slough North	0.20	0.52	0.41	0.38
Armstrong Slough South	0.05	0.11	0.17	0.11
Peavine	0.02	0.09	0.20	0.10
Wildcat East	0.01	0.02	0.04	0.02
Wildcat West	0.03	0.02	0.01	0.02
Wildcat All	0.07	0.01	0.04	0.04
Ash Slough East	0.00		0.00	0.00 (2 year average)
Ash Slough West	0.49		0.67	0.58 (2 year average)
SEZ Dairy	2.34	1.20	9.38	4.31

TOTAL N

Site/Watershed	1979-80	1980-81	1981-82	Annual Average
Armstrong Slough North	3.16	6.70	8.63	6.16
Armstrong Slough South	1.50	4.58	12.88	6.32
Peavine	1.91	6.68	15.82	8.14
Wildcat East	0.98	1.00	2.36	1.45
Wildcat West	1.20	0.85	0.63	0.89
Wildcat All	2.28	0.09	3.57	1.98
Ash Slough East	3.02		2.33	2.68 (2 year average)
Ash Slough West	13.07		18.34	15.71 (2 year average)
SEZ Dairy	8.02	8.30	29.12	15.15

ORTHO P

Site/Watershed	1979-80	1980-81	1981-82	Annual Average
Armstrong Slough North	0.13	0.71	0.13	3.20
Armstrong Slough South	0.01	0.10	0.11	0.07
Peavine	0.01	0.07	0.06	0.05
Wildcat East	0.01	0.01	0.01	0.01
Wildcat West	0.01	0.01	0.01	0.01
Wildcat All	0.02	0.01	0.01	0.01
Ash Slough East	0.45		0.15	0.30 (2 year average)
Ash Slough West	6.76		5.83	6.30 (2 year average)
SEZ Dairy	2.88	4.29	9.95	5.71

TOTAL P

Site/Watershed	1979-80	1980-81	1981-82	Annual Average
Armstrong Slough North	0.28	1.02	0.29	0.53
Armstrong Slough South	0.06	0.25	0.43	0.25
Peavine	0.04	0.29	0.33	0.21
Wildcat East	0.02	0.02	0.04	0.03
Wildcat West	0.05	0.03	0.01	0.03
Wildcat All	0.03	0.06	0.15	0.08
Ash Slough East	0.59		0.20	0.40 (2 year average)
Ash Slough West	7.89		6.93	7.41 (2 year average)
SEZ Dairy	4.08	5.08	11.68	6.95

IIIe

ANNUAL LOADING AND UPTAKE RATES ON ARMSTRONG SLOUGH MARSH

(kg/ha/yr)

TOTAL NITROGEN

	1979-80	1980-81	1981-82
Load	973.0	2,151.0	3,578.0
Uptake	634.0	688.0	-187.0
% Uptake	65.2	32.0	-5.2

INORGANIC NITROGEN

	1979-80	1980-81	1981-82
Load	56.7	143.3	129.5
Uptake	48.8	93.9	65.7
% Uptake	86.0	65.6	50.8

TOTAL PHOSPHORUS

	1979-80	1980-81	1981-82
Load	79.2	282.1	128.9
Uptake	62.7	121.3	-32.3
% Uptake	79.2	43.0	-25.1

ORTHO PHOSPHORUS

	1979-80	1980-81	1981-82
Load	34.9	191.0	52.9
Uptake	29.0	79.7	1.9
% Uptake	83.3	41.7	3.6

FLOWS (CUBIC METERS X 1000)

	1979-80	1980-81	1981-82
Flows In	7,692	10,175	28,046
Volume Loss	4,505	3,046	-2,634
% Volume Loss	58.6	29.9	-9.4

IIIf

ANNUAL LOADING AND UPTAKE RATES ON ASH SLOUGH MARSH

(kg/ha/yr)

TOTAL N

	1979-80	1980-81	1981-82
Load	190.4	16.7	250.2
Uptake	53.2	16.7	9.1
% Uptake	27.9	100	3.6

INORGANIC N

	1979-80	1980-81	1981-82
Load	15.8	6.7	17.3
Uptake	13.0	6.7	6.8
% Uptake	82.3	100.0	39.1

TOTAL P

	1979-80	1980-81	1981-82
Load	98.8	1.3	85.6
Uptake	43.2	1.3	29.2
% Uptake	43.7	100	34.1

ORTHO P

	1979-80	1980-81	1981-82
Load	84.0	0.9	71.7
Uptake	37.0	0.9	28.3
% Uptake	44.0	100	39.5

FLOWS (CUBIC METERS X 1000)

	1979-80	1980-81	1981-82
Flows In	546.4	58.6	665.2
Volume Loss	181.6	58.6	165.5
% Volume Loxx	33.2	100.0	24.9